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STUDIES IN THE PHYSIOLOGY AND CYTOLOGY OF USTILAGO ZEAE AND SOROSPORIUM REILIANUM[1]

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INTRODUCTION

Two smuts of corn are known to occur in the United States. The one of greater importance from the standpoint of distribution and loss is caused by *Ustilago zeae* (Bekm.) Ung. This fungus, widely distributed in the great corn-growing region of the Middle West, may infect the actively growing tissues of the corn plant at any stage in the plant's growth. The conspicuous smut galls, which appear at or near points of infection, may produce stunting of the plants, and, if the female inflorescence is involved, the ears may fail to develop. The other smut is caused by *Sorosporium reilianum* (Kühn) McAlpine. In the Pacific-Coast regions this fungus is found commonly on corn, but in other parts of the United States it is confined chiefly to sorghum. In Australia, however, corn smut is caused almost entirely by *S. reilianum*. It is generally considered that plants are infected by this fungus in the seedling stage. From then on, the growth of the parasite is systemic in the tissues of the host plant, and, at maturity, the inflorescence generally becomes a powdery mass of chlamydospores. It is of interest that Reed, Swabey, and Kolk (30) have found recently that *S. reilianum* is composed of two physiologic strains, one of which occurs on corn and the other on sorghum.

HISTORICAL REVIEW

The working out of the life histories of the smuts has contributed one of the most interesting chapters in the development of plant pathology. A number of early investigators had observed that in certain smuts cell fusions occurred frequently. In some species these fusions take place between neighboring sporidia; in others, between two cells of the promycelium. De

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Bary pointed out the similarity between these unions and the sexual fusions which occur in the Conjugateae, and suggested that the cell fusions in the smuts might represent a reduced sexual process. Brefeld firmly opposed this interpretation. He maintained that these cell fusions were merely vegetative unions and that the smuts were entirely lacking in any form of sexual reproduction.

The first extensive investigation of the nuclear phenomena in the life history of the smut fungi was made by Dangeard (11). He studied a number of species belonging to the genera Entyloma, Tilletia, Urocystis, and Ustilago, and found the chlamydospores to be uninucleate and, on germination, to produce promycelia, each cell of which contained a single nucleus. If sporidia budded from the promycelium, they, too, were uninucleate. The young chlamydospores produced in the host plant were binucleate but, as they matured, the two nuclei fused so that each ripe chlamydospore contained but a single nucleus. This nuclear fusion in the chlamydospore was regarded by Dangeard as a reduced sexual process. Harper (19), working with *Ustilago maydis, U. antherarum,* and *U. scabiosa,* confirmed Dangeard's observations regarding the fusion of the two nuclei in the chlamydospore.

Harper had investigated the fusions between sporidia and those between promycelial cells, but he observed no migration of protoplasm from one cell to the other, and the nuclei appeared to remain in their respective cells throughout the entire process. However, in 1910, Lutman (27) found that, when the promycelial cells of *U. hordei, U. avenae,* and *U. tritici* conjugate in pairs, the nucleus from one cell passes over into the other cell, where the two nuclei come to lie side by side. He examined the tissue of plants infected with *U. levis* and *U. maydis,* respectively, and found the mycelium of both smuts to be made up of multinucleate cells. Immediately before spore formation began, certain cells appeared to contain each a pair of nuclei which later fused, so that the mature spore contained but a single nucleus. The possible relationship between the nuclei which become associated during the fusion of two sporidia or of two promycelial cells and the pair of nuclei which finally fuse in the chlamydospore appears to have been overlooked by Lutman, for he states: "In the smuts the morphological equivalents of the oogone and the antherids are the fused conidial or promycelial cells. Functionally the fusion of the cells is no longer of much importance in the life cycle of the smut but they still represent the primitive gametes. In the Basidiomycetes cell fusion has disappeared entirely but in the smuts it is retained in a rudimentary state and is only functional in a limited fashion under certain conditions."

In 1912, Rawitscher (29) investigated the life histories of *U. carbo* and *U. maydis.* When the spores of *U. carbo* germinated, fusions were observed

to take place either between the promycelial cells or between the sporidia produced from cells which had not fused. After fusion, the nucleus from one cell passed over to the other cell. The mycelium in the tissues of the host plant was found to consist of binucleate cells, and not multinucleate cells, as had been observed by Lutman. At the time of spore formation, the pair of nuclei in each cell fused, thus giving rise to uninucleate chlamydospores. In *U. maydis,* no fusions were observed to take place between promycelial cells or between sporidia. The cells of the mycelium in the host plant were uninucleate and, immediately before spore formation, these cells appeared to fuse in pairs, the nucleus from one cell passing into the neighboring cell. The resulting binucleate cell rounded itself off and the two nuclei fused, thus producing a uninucleate chlamydospore. As a result of his observations, Rawitscher (29) concluded that the two nuclei which eventually unite in the chlamydospore of *U. carbo* are the direct descendants of the two nuclei which become associated during the fusion of two sporidia or two promycelial cells. In *U. maydis,* the cycle of events was believed to be essentially the same as in *U. carbo,* with the important difference, however, that in the former smut no sporidial fusions occur, the association of nuclei taking place only at the time of spore formation. Because of this delayed nuclear association, almost the complete life cycle of the smut appeared to be passed in the haploid condition.

Rawitscher found no clamp connections on the parasitic mycelium of *U. maydis,* but Seyfert (32), in a recent paper, figures numerous clamp connections and also shows that the binucleate condition arises some time before spore formation.

A number of investigators had observed that sporidial fusions occur in certain smuts, but Kniep (22) was the first to show that these fusions take place only between certain sporidia. In *U. violacea,* he demonstrated the existence of two kinds of sporidia, A and B, present in approximately equal numbers. Fusions occurred only when A sporidia and B sporidia were brought together. Kniep suggested that the physiological differences in the sporidia were determined by sex factors and that during the nuclear divisions accompanying spore germination, a segregation of these factors took place resulting in the production of two kinds of sporidia of opposite sex.

In the smut fungi, therefore, a well-defined alternation of generations seems to occur. The mature chlamydospore contains a single diploid nucleus. During the nuclear divisions which accompany the germination of the spore, a reduction takes place, with the result that each promycelial cell and each sporidium receives a single haploid nucleus. In some species, the binucleate condition is then initiated by the conjugation of sporidia or of promycelial cells; in others, *e.g., U. zeae,* by the conjugation of neighboring cells of the mycelium within the host plant. This binucleate condition per-

sists until immediately before spore formation when the two nuclei in each cell fuse and chlamydospores once more are formed, each containing a single diploid nucleus.

USTILAGO ZEAE

Earlier investigations

Brefeld (5) made a careful study of spore germination in *U. zeae* and showed how the germ tubes from the sporidia infect the corn plant. He believed that the chlamydospores borne in the smut galls germinated in the soil and produced sporidia which, in turn, were able to multiply by a process of yeast-like budding. These sporidia were then carried off by the wind, and, settling upon the growing tissues of the corn plant, sent out germ tubes which caused infection by direct penetration of the epidermis.

At the time when Brefeld made his experiments, very little was known of the nuclear phenomena which occur during the life history of the smuts. More recently, however, Rawitscher (29) established the fact that in *U. zeae* an alternation takes place between the haploid and the diploid condition. He believed the haploid condition to extend from the time of chlamydospore germination to a period immediately before spore formation. The diploid phase, therefore, was restricted to a single cell which, at maturity, became the chlamydospore. This would mean that almost the complete life cycle of *U. zeae*, including the parasitic stage, is passed in the haploid condition.

The work of Stakman and Christensen (34) demonstrated that in all probability *U. zeae* is heterothallic. The cultures which they employed in their experiments originated from a number of chlamydospores, but they were grown separately for periods ranging from one to three years and, at the time the inoculations were made, each culture appeared to be pure as to type of growth. They found that these cultures produced no galls when injected singly into corn plants, but when paired together in certain combinations they produced an abundance of galls. It was concluded, therefore, that *U. zeae* is made up of at least two sexual strains, and that gall formation takes place only when these two strains are brought together in the host plant.

Outline of investigations

The present investigation is a continuation of the work of Stakman and Christensen. The main points to be investigated were: (1) The behavior of the nuclei during spore germination; (2) the capacity of monosporidial cultures to produce galls on injured and uninjured plants; (3) the capacity of various combinations of monosporidial cultures to produce galls on injured and uninjured plants; (4) the behavior of monosporidial cultures from chlamydospores collected in different districts when paired together in the host plant; and (5) the period at which hyphal fusion and pairing of the nuclei occur in the host plant.

Spore germination

Germination of the spores of *U. zeae* has been figured by Brefeld (5), Hitchcock and Norton (20), Clinton (9), and Stakman (33). Maire (28) gave illustrations showing the nuclei of the budding sporidia. However, the writer has been able to find only two figures showing the nuclei during spore germination; they are given in a paper by Istvanffi (21), published in 1895.

Spores germinate readily on 1 per cent malt agar. In order to obtain material for a study of the nuclei during germination, a thin film of this medium was spread on one side of a glass slide and the spores were dusted on the surface of the film with a small camel's-hair brush. The slides were then inverted over glass rods in a petri dish containing a few drops of distilled water. When the desired stage of germination had been reached, the material was fixed by adding a few drops of Flemming's weaker solution which was allowed to act for about 15 minutes. The fixative was then removed by carefully adding a few drops of distilled water and sucking up the excess liquid with filter-paper. In order to prevent the spores from being washed off during the process of staining, the slides were passed first into a bath of ether, and then into a 0.2 per cent solution of collodion made up with equal parts of alcohol and ether, as suggested by Kniep (24). The thin film of collodion left on the slide prevented the spores from being washed off during subsequent manipulations. The material was stained in haematoxylin (Heidenhain's method), given a short counter stain in erythrosin, and finally mounted in balsam.

The various stages of spore germination and the budding of the sporidia are shown in Plate VII, 1–19. The first division of the fusion nucleus takes place in the chlamydospore. When the promycelium has been produced, one of the daughter nuclei migrates into it, while the other one remains in the spore. The two nuclei then undergo a second division and one of the nuclei from the spore moves up into the base of the promycelium, thus giving three nuclei to the promycelium and one to the spore. Three septa are generally formed, separating the nuclei from one another, but sometimes it is difficult to see them, even in stained preparations. The sporidia usually appear at definite positions on the promycelium—at the tip, at the upper ends of the central cells, and at the junction between the promycelium and the spore. Before the sporidium has reached full size, the nucleus in the promycelial cell divides, and one daughter nucleus migrates into the sporidium while the other one remains in the cell. In this way, a promycelium is able to produce several successive generations of sporidia. By using the spore isolator (18), three generations of sporidia were removed from a promycelium and a fourth generation was seen to develop a short

time afterwards. This process of sporidial production is illustrated in Plate VII, 15.

The sporidia generally are uninucleate. However, some sporidia may have two or more nuclei. On nutrient media, they reproduce by budding. The behavior of the nuclei in this process is shown in Plate VII, 16–19.

The Effect of Injecting Corn Plants with Individual Monosporidial Cultures and with Various Combinations of these Cultures

Cultures were made from four different collections of chlamydospores. Three of these collections, A, B, and C, were obtained from corn grown on plots at University Farm, St. Paul. The third, D, was sent to Dr. Stakman by Professor Pantanelli, of Bari, Italy. Single chlamydospores were placed in hanging drops of 1 per cent malt agar and, when they had germinated, the sporidia were removed from the promycelia and propagated separately. The method of isolating the individual sporidia has been described in a separate paper (18). Inoculum for the infection experiments was obtained by transferring each monosporidial culture to an Erlenmeyer flask containing a nutrient solution composed of 1 per cent malt extract and 2 per cent dextrose. In this solution the sporidia multiplied very rapidly.

Corn plants of the variety Golden Bantam were used in all of the experiments. They were grown in pots in the greenhouse, each pot having eight plants. The plants were inoculated when they were about four weeks of age, the nutrient solution containing the sporidia being injected into the growing points of the stems by means of a hypodermic syringe. When plants were to be inoculated with a combination of two monosporidial cultures, the mixing of the cultures was performed in a sterile Erlenmeyer flask immediately before inoculation. One pot of eight plants was used for each inoculation, and all experiments were made in duplicate. Plants inoculated with sterile nutrient solution were employed as checks.

Sporidia were isolated from seven chlamydospores. Two of these chlamydospores were taken from collection A, three were from collection C, and one was taken from each of the collections B and D. Where possible, a record was kept of the position on the promycelium occupied by each sporidium, and for convenience the sporidia were numbered 1, 2, 3, and 4, from the tip of the promycelium to the spore. A number was also given to the chlamydospore from each collection. Thus, A21 refers to the sporidium at the tip of the promycelium produced from spore number 2 of collection A. In the case of spores C1 and C3, the four sporidia were isolated from each promycelium but it was not possible to determine the relative positions which they occupied. The numbers which have been given to these sporidia, therefore, do not refer to the positions which they occupied on the promycelia.

The results of inoculating corn plants with monosporidial cultures used singly and also combined in various ways are presented in tabular form. The sign (+) indicates that the inoculated plants produced galls; the sign (−) indicates that no galls appeared.

It is of interest to note, first of all, that whereas certain cultures when combined together produced galls, none of the 28 monosporidial cultures when injected alone was capable of inducing gall formation. This result confirms the conclusion of Stakman and Christensen that *U. zeae* is heterothallic and shows that galls are produced only when plants are infected by two cultures originating from sporidia of different sex.

All of the possible combinations were made between cultures of the four sporidia from each of the eight chlamydospores. On the basis of these reactions, it is possible to divide the chlamydospores into three groups: (1) Those which produced two sporidia of one sexual group and two of the opposite sexual group; (2) those which produced sporidia of four sexual groups; (3) those which produced three sporidia of one sexual group and one of the opposite group.

The production of sporidia or promycelial cells belonging to two sexual groups seems to be quite common in the smuts. This condition, first reported by Kniep (22) in *Ustilago violacea*, has since been observed in several other species. In *U. zeae*, five of the seven chlamydospores investigated produced promycelia bearing two sporidia of one sex and two of the opposite sex. However, the sporidia were found to be arranged on the promycelia in two different ways. The sporidia from spores C2 and D1 were grouped so that numbers 1 and 2 were of one sex and 3 and 4 were of the opposite sex. Table 1, giving the reactions of the sporidia from spore D1, illustrates this condition. The arrangement of the sporidia from spores

		AB		ab	
		1	2	3	4
AB	1	−	−	+	+
	2	−	−	+	+
ab	3	+	+	−	−
	4	+	+	−	−

TABLE 1.—Gall formation in corn plants inoculated with sporidia of *Ustilago zeae*. Cultures of the four sporidia from chlamydospore D1 (Italy) were used singly and in pairs.

		AB	ab	AB	ab
		1	2	3	4
AB	1	−	+	−	+
ab	2	+	−	+	−
AB	3	−	+	−	+
ab	4	+	−	+	−

TABLE 2.—Gall formation in corn plants inoculated with sporidia of *Ustilago zeae*. Cultures of the four sporidia from chlamydospore B1 (Minnesota) were used singly and in pairs.

A2 and B1 was such that numbers 1 and 3 were of one sex and 2 and 4 were of the opposite sex. This condition is illustrated by the reactions of the sporidia from spore B1, as shown in table 2. Spore C3 produced two sporidia of one sex and two of the opposite sex, but the positions of the sporidia on the promycelium were not recorded.

It has been shown (17) that some of the basidia of *Coprinus lagopus* may bear spores belonging to four sexual groups. The genetic constitution of these spores is such that when their mycelia are paired in all possible ways only two combinations result in diploid mycelia having clamp connections. Up to the present, a condition analogous with this has not been reported in the smut fungi. In *U. zeae*, however, a single promycelium may produce sporidia of four different kinds, as is shown in table 4. This type of sporidial production was found only in chlamydospore A1. When cultures of the four sporidia from this chlamydospore were paired in all possible ways and injected into corn plants, it was found that galls were produced by the combination of sporidia 1 and 3, and by 2 and 4, but by no others.

	AB		ab	
	1	2	3	4
AB 1	—	—	+	⊕
AB 2	—	—	⊕	+
ab 3	+	⊕	—	—
ab 4	⊕	+	—	—

TABLE 3.—Gall formation in corn plants inoculated with sporidia of *Ustilago zeae*. Cultures of the four sporidia from chlamydospore C2 (Minnesota) were used singly and in pairs.

	AB	Ab	ab	aB
	1	2	3	4
AB 1	—	—	+	—
Ab 2	—	—	—	+
ab 3	+	—	—	—
aB 4	—	+	—	—

TABLE 4.—Gall formation in corn plants inoculated with sporidia of *Ustilago zeae*. Cultures of the four sporidia from chlamydospore A1 (Minnesota) were used singly and in pairs.

The reactions of the sporidia from spore C2 suggest a condition intermediate between the bisexual type of spore D1 and the so-called quadrisexual type of spore A1. As is shown in table 3, the sporidia from this spore fall into two groups, 1 and 2 being of one sex and 3 and 4 of the opposite sex. However, two of the matings—1 with 4, and 2 with 3—produced only a few small galls. In the table, these weak reactions have been denoted by circles about the (+) signs. A comparison of tables 3 and 4 will show that, had sporidia 1 and 4, and 2 and 3, of table 3, failed to produce any galls, a grouping identical with that in table 4 would have been obtained.

On the other hand, had these matings produced the normal number of galls, table 3 would have been identical with table 1.

The reactions of the sporidia from spore C1 are presented in table 5. These sporidia belong to two sexual groups, but instead of occurring in pairs, this tetrad has three sporidia of one sex and only one of the opposite sex. Unfortunately, the order in which they occurred on the promycelium is not known, but it is probable that the nucleus of one of the promycelial cells degenerated and that one of the others produced two sporidia. A condition suggesting this may be seen in Plate VII, 12, where the promycelial cell immediately above the chlamydospore appears to be producing sporidia from two places.

	AB 1	AB 2	ab 3	AB 4
AB 1	—	—	+	—
AB 2	—	—	+	—
ab 3	+	+	—	+
AB 4	—	—	+	—

TABLE 5.—Gall formation in corn plants inoculated with sporidia of *Ustilago zeae*. Cultures of the four sporidia from chlamydospore C1 (Minnesota) were used singly and in pairs. (Relative positions of the sporidia on the promycelium were not determined.)

		AB		ab	
		D11	D12	D13	D14
ab	C31	+	+	—	—
	C32	+	+	—	—
AB	C33	—	—	+	+
	C34	—	—	+	+

TABLE 6.—Gall formation in corn plants inoculated with sporidia of *Ustilago zeae*. Cultures of the four sporidia from chlamydospore D1 (Italy) were paired with cultures from the four sporidia of chlamydospore C3 (Minnesota).

Some species of the Hymenomycetes, *e.g.*, *Schizophyllum commune* (25) and *Coprinus lagopus* (17), have been shown to be composed of distinct geographical strains and, when monosporous mycelia from two strains are paired together, all of the matings produce diploid mycelia bearing clamp connections. Vandendries (35) has shown recently that certain strains of *Coprinus micaceus* exhibit a high degree of intersterility. A few matings were made between monosporidial cultures of *U. zeae* obtained from different collections of chlamydospores, but no evidence of complete interfertility or intersterility was obtained. The four monosporidial cultures from spore C3 of the Minnesota collection reacted in a perfectly normal manner with the four monosporidial cultures of spore D1 from Italy. The results of these matings, given in table 6, show that the two sexual groups of the Minnesota cultures are identical with those of the Italian cultures.

Reduction and Segregation during Spore Germination

In certain respects the fungi are particularly suitable objects for a study of the inheritance of Mendelian characters. Many species complete their life cycles in a relatively short time and, unlike the higher plants, the haplonts may be kept in culture and used for any number of experiments. In spite of this fact comparatively little work has been done on the genetics of the fungi. Probably the most extensive investigations have been made in connection with the reactions of monosporous mycelia of some of the Basidiomycetes and Ascomycetes. Kniep (25) and others have interpreted their results in terms of "sex factors," while Brunswick (6) has employed the term "sterility factors." By using the latter term the reactions of these fungi are brought in line with somewhat similar phenomena in some of the higher plants; but, whichever term is employed, the genetic interpretation of the results is the same.

A relatively large number of matings would be required in order to make a thorough study of the factors determining the reactions of monosporidial cultures of *U. zeae*. However, with the data available, some interesting possibilities are suggested.

The reactions of the four sporidia from spore A1 (table 4) can be explained best by assuming that two pairs of factors—(Aa) and (Bb)—are involved and, furthermore, that these factors are borne in different chromosomes. The fusion nucleus of the chlamydospore, therefore, must possess the two pairs of homologous chromosomes bearing the factors (Aa Bb). When the spore germinates, the nucleus divides twice and segregation of these factors takes place so that each nucleus of the promycelium receives one factor from each pair. Each sporidium, in turn, will receive a single haploid nucleus from its promycelial cell. The genetic constitution of the sporidia will depend upon the time of chromosome reduction and also upon the manner in which segregation has occurred. A reduction of both pairs of chromosomes in the first division would result in the promycelium bearing two sporidia of one sex and two of the opposite sex. According to this method of segregation, the sporidia might be represented as (AB), (AB), (ab), (ab), or (Ab), (Ab), (aB), (aB). Obviously, this arrangement would not explain the reactions of the sporidia from spore A1. A reduction of both pairs of chromosomes in the second division might produce sporidia of two kinds, or of four kinds, according to the manner in which segregation took place. Of the promycelia bearing sporidia of two kinds, some might have two sporidia with the factors (AB) and two with the factors (ab); others might have two sporidia with the factors (Ab) and two with the factors (aB). Furthermore, it would be possible for the sporidia on each of the two types of promycelia to be arranged in any

one of four different ways. All of the eight possible arrangements would be different from those which might occur as a result of reduction in the first nuclear division. If the sporidia were of four kinds—(AB), (ab), (Ab), (aB)—they might be arranged also in eight possible ways. The sporidia from spore A1 are all different, since pairing occurred only between numbers 1 and 3 and numbers 2 and 4; but the order in which they were borne on the promycelium does not agree with any of the eight possible arrangements which might result from the reduction of both pairs of chromosomes in the second division. The only other possibility is that one pair of chromosomes separated in the first division and the other pair in the second division. This type of segregation is illustrated in figure 1. Such a scheme would result in the production of four kinds of sporidia so

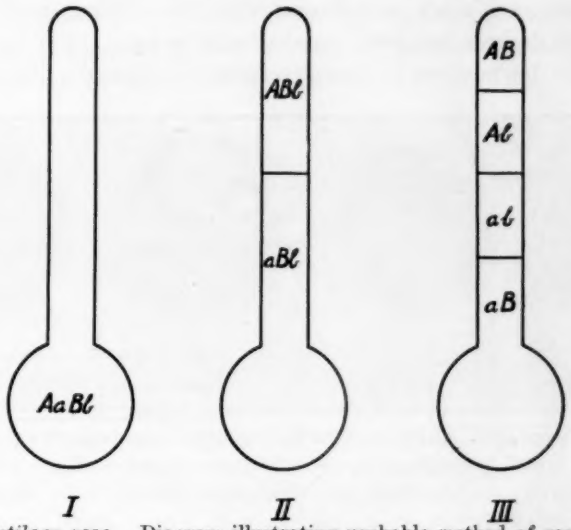

FIG. 1.—*Ustilago zeae*. Diagram illustrating probable method of segregation in the promycelium of spore A1. I: The fusion nucleus of the spore at time of germination possesses both pairs of factors. II: Segregation of the factors (Aa) occurs at the first nuclear division. III: Factors (Bb) segregate at the second division.

arranged that reactions would take place only between numbers 1 and 3 and numbers 2 and 4. As the sporidia of spore A1 were arranged on the promycelium in this order, it seems reasonable to conclude that one pair of homologous chromosomes separated in the first division and that the other pair separated in the second division.

Spores C2 and D1 produced sporidia of two kinds only, numbers 1 and 2 being of one sex and numbers 3 and 4 of the opposite sex, so that segregation of both pairs of factors must have taken place during the first division of

the fusion nucleus. This paired arrangement of the sporidia is illustrated in table 1. Two other spores—A2 and B1—also produced sporidia of two kinds only, but instead of being arranged in pairs on the promycelium, the sporidia of the same sex occurred alternately, numbers 1 and 3 being of one sex and numbers 2 and 4 of the opposite sex. This condition is shown in table 2. Such an arrangement could come about only by a segregation of both pairs of factors during the second division of the fusion nucleus.

Although the sporidia of spore B1 belong to only two sexual groups, they may be classified further on the basis of their cultural characters. When the sporidia had been removed from the promycelium and were growing in hanging drops of nutrient agar, it was seen that numbers 1 and 2 produced an abundance of sporidia and that numbers 3 and 4 produced a mycelial type of growth with relatively few sporidia. These morphological differences were even more pronounced when the cultures were transferred to Erlenmeyer flasks containing potato-dextrose agar. The appearance of the cultures on this medium is shown in figure 2. Sporidia 1 and 2 from the

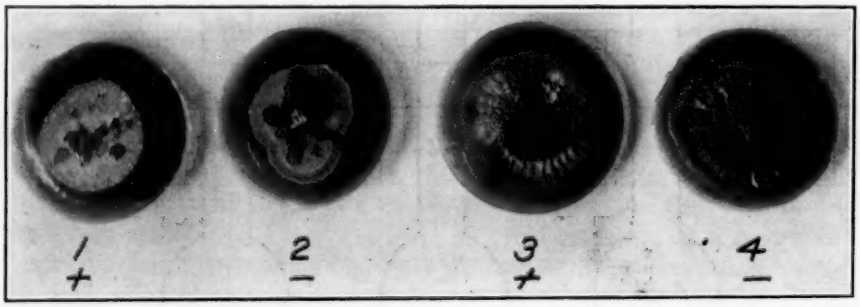

FIG. 2.—*Ustilago zeae*. Cultures of the four sporidia from spore B1 on potato-dextrose agar. Colonies 1 and 2 consist of sporidia; colonies 3 and 4 of a reddish-brown mycelium. The sporidia are numbered, according to position, from the tip of the promycelium to the chlamydospore.

two terminal cells of the promycelium gave white, yeast-like colonies, whereas, sporidia 3 and 4 from the two lower cells produced a reddish-brown mycelial growth. Therefore, although segregation of the sex factors must have taken place during the second nuclear division, the factors determining color and type of growth must have segregated with the first division of the fusion nucleus. This indicates also that the sexual reaction of a culture is not necessarily linked with a particular type of growth on artificial media.

From the evidence just presented, it would appear that in *U. zeae* a segregation of factors may take place during either the first or the second division of the fusion nucleus. Thus, in two spores (C2 and D1) segrega-

tion was completed at the first division; in one (A2) at the second division; while in two spores (A1 and B1) there is evidence of segregation at both divisions. Although botanists generally have favored the idea of pre-reduction, there is good reason to believe that, in both plants and animals, segregation may take place at either the first or the second division of the fusion nucleus. In the fungi, evidence in support of segregation at the second division was advanced by Funke (16) for *Hypholoma fasciculare* and *Collybia velutipes* and by the writer (17) for *Coprinus lagopus*. Allen (1) found that in *Sphaerocarpos donnellii* quantitative segregation might take place at both divisions. The cytological investigations bearing on chromosome reduction in insects were reviewed recently by Carothers (7). She concludes that, although either pre-reduction or post-reduction may occur, a given pair of chromosomes always behave in a predictable manner. Thus, one pair may always separate at the first division, another pair always at the second division, while a third pair may separate sometimes at the first division and sometimes at the second division.

		AB A11	Ab A12	ab A13	aB A14
AB	A21	—	—	+	—
ab	A22	+	+	—	—
AB	A23	—	—	+	+
ab	A24	—	+	—	—

TABLE 7.—Gall formation in corn plants inoculated with sporidia of *Ustilago zeae*. Cultures of the four sporidia from chlamydospore A1 (Minnesota) were paired with cultures from the four sporidia of chlamydospore A2 (Minnesota).

		AB 1	ab 2	Ab 3	aB 4
AB	1	—	+	—	—
ab	2	+	—	—	—
Ab	3	—	—	—	+
aB	4	—	—	+	—

TABLE 8.—Gall formation in corn plants inoculated with sporidia of *Sorosporium reilianum*. Cultures of the four sporidia from a single chlamydospore were used singly and in pairs. (The relative positions of the sporidia on the promycelium were not determined).

It has already been stated that the four sporidia from spore A1 were all different sexually, while those from spore A2 fell into two sexual groups only, numbers 1 and 3 being of one sex and numbers 2 and 4 of the other sex. As both chlamydospores were taken from the same smut collection, the question naturally arose as to the behavior of the eight monosporidial cultures when paired together. According to theory, positive reactions might be expected to occur only in the following combinations: A11 × A22, A11 × A24, A13 × A21, and A13 × A23. However, when the experiments were carried out, six fertile combinations appeared, only three of which would

have been expected on theoretical grounds. The results are shown in table 7. This suggests that in the sporidia of some chlamydospores more than two pairs of factors may be involved in determining sexual reaction.

Infection of Uninjured Plants

In the experiments already described, it was found that no galls were produced when individual monosporidial cultures of *U. zeae* were injected into young corn plants. The question still remained as to whether or not the germ tube from a single haploid sporidium is capable of penetrating the uninjured epidermis and causing infection. In view of Rawitscher's (29) conclusion that conjugation takes place in the tissues of the host plant immediately before spore formation, it would appear *a priori* that the haploid germ tubes are able to penetrate the epidermis and develop an extensive parasitic mycelium. However, Zillig (36) considered that the haploid sporidia of *U. violacea* were unable to cause infection, and Dickinson (14) has shown recently that no infection results when seedlings are inoculated with sporidia of one sex of *U. hordei* or *U. levis*, but only when sporidia of the two sexes are combined.

The ability of the haploid sporidia of *U. zeae* to cause infection of uninjured plants was tested by inoculating corn seedlings one week old with the following monosporidial cultures: (1) C31, (2) C33, (3) a mixture of C31 and C33. In earlier experiments these cultures had been found to be of opposite sex. One series of inoculations was made with a nutrient solution (1 per cent malt extract and 2 per cent dextrose) containing the sporidia which had grown in it, while a second series was made with sporidia grown in test tubes of potato-dextrose agar and then scraped off and suspended in sterile distilled water. The liquid containing the sporidia was drawn into sterile pipettes and dropped on the leaves of the young seedlings. After the inoculations were made, the plants were placed in a moist chamber for 48 hours, and then removed to the greenhouse bench. As a control, other plants were treated in the same manner with (1) fresh sterile nutrient solution and (2) nutrient solution from which the sporidia had been removed by passage through a porcelain filter.

Eight days after inoculation, the plants were examined for signs of infection. The presence of small chlorotic areas on the parts of the leaves where the sporidia had been placed was considered as evidence that penetration had taken place. Pieces of the epidermis were stripped off, stained in aniline blue, and examined under the microscope. In plants inoculated with two monosporidial cultures of opposite sex, the hyphae are quite large and can be made out even without the aid of any stain. In plants inoculated with a single monosporidial culture, however, the hyphae resemble very fine threads and it is often extremely difficult to find them.

TABLE 9.—*Inoculation of uninjured corn seedlings with single monosporidial cultures of Ustilago zeae and with two such cultures of opposite sex*

Inoculum	No. of plants inoculated	No. of plants infected
C 31, in nutrient solution	14	13
C 33, do	16	10
C 31 × C 33, do	14	13[a]
C 31, in distilled water	16	4
C 33, do	16	3
C 31 × C 33, do	16	6
Sterile nutrient solution	8	No injury
Filtrate from sterile nutrient solution	8	do

[a] Twenty-four days after inoculation, 9 of these plants were completely killed by galls which formed on the stems just above the soil level.

The results of the inoculation of uninjured seedlings are summarized in table 9. No difficulty was experienced in infecting uninjured seedlings with a single monosporidial culture. When the inoculations were made with sporidia suspended in the nutrient solution in which they had grown, the infective power of a single monosporidial culture was about equal to that of a mixture of two such cultures of opposite sex. But the plants inoculated with a single culture showed no signs of injury apart from the flecking of the leaves: whereas, 9 of the 14 plants inoculated with a mixture of two cultures of opposite sex were completely killed. A relatively light infection was obtained by inoculating with sporidia grown on nutrient agar and suspended in distilled water. In this series a greater number of infections was obtained with a combination of two cultures of opposite sex than with a single monosporidial culture. This apparent difference may be due, in part, to the difficulty of detecting a very light infection by a single monosporidial culture.

The greater number of infections obtained with sporidia suspended in nutrient solution as compared to those in distilled water might appear to be due to some substance in the solution which had an injurious action on the epidermal cells of the leaves, thus allowing the sporidial germ tubes to penetrate more readily. Yet, this could not have been the case, since the leaves treated with the filtrate from a solution in which sporidia had grown showed no sign of injury. It was noticed that the nutrient solution containing the sporidia spread evenly over the leaves and that the distilled water tended to collect in drops. The sporidia suspended in the nutrient solution, therefore, would come in closer contact with the epidermal cells and would be more likely to cause infection.

The Origin of the Diploid Mycelium

The sporidia of many of the smuts when grown on certain culture media conjugate in pairs. Maire (28) believed fusions to take place between the sporidia of *U. zeae*, and he published one figure illustrating this process. However, the nuclei were not shown, and his figure suggests the budding off of a new sporidium rather than the process of conjugation. Sartoris (31) also stated that the sporidia of *U. zeae* conjugate, but he gave no illustrations in support of his observations. Other workers have been unable to obtain any evidence that the sporidia of this species conjugate in pure culture. During the course of the investigations recorded in this paper, sporidia which were known to be of opposite sex were grown together on several different media but no sign of sporidial fusions was ever observed. Mixtures of the two kinds of sporidia were placed also on the surface of corn leaves floated on water in petri dishes, and after 48 hours they were removed and examined under the microscope, but the results of these trials were always negative. The question of sporidial fusions must, for the present, await further experiment, but it seems clear that the conditions which stimulate this process in many other smuts are without effect on the sporidia of *U. zeae*.

As a result of cytological investigations, Rawitscher (29) concluded that the pairing of nuclei and the formation of the diploid mycelium were brought about by the fusion of neighboring hyphae in the tissues of the host plant immediately before the formation of chlamydospores. Rawitscher's observations have been responsible for the view now generally accepted, *viz*, that the parasitic stage of *U. zeae* is passed almost entirely in the haploid condition, the diploid phase being restricted to a brief period immediately preceding spore formation. However, in a recent paper, Seyfert (32) stated that he was able to find mycelium possessing clamp connections and paired nuclei some distance from the point of gall formation.

On one occasion during the present investigation it was possible to observe the exact point at which fusion of the haploid mycelia and association of the nuclei took place. Sporidia from two monosporidial cultures of opposite sex were mixed together and dropped on the leaves of young corn seedlings growing in pots in the greenhouse. Immediately after inoculation, the plants were removed to a moist chamber for 48 hours, and then were placed on the greenhouse bench. Eight days after the inoculations were made, pieces of the epidermis were stripped from the leaves at the point of inoculation, stained in aniline blue, and examined under the microscope. In one preparation (Plate VII, 20) it was found that two sporidia lying close together had sent out germ tubes which penetrated the upper wall of the epidermal cell. The thread-like infection hyphae then grew across the cell and

came together to form a stout diploid hypha in which several pairs of nuclei could be seen. The contrast in the size of the haploid and diploid mycelia was very striking. At three points on the diploid mycelium there were protuberances suggesting clamp connections, but the cross walls could not be made out. In many other preparations, however, numerous clamp connections were found. One of them is shown in Plate VII, 21. The hypha bearing this clamp connection pushed its way out through the upper wall of the epidermis, grew along the surface of the leaf, and penetrated the epidermis again beside a stomatal cell.

The experiments described in the foregoing seem to show conclusively that the germ tubes from haploid sporidia are able to infect young corn plants. The mycelium resulting from these infections consists of very fine threads and apparently is incapable of further parasitic development. But, if a plant has been infected by two sporidia of opposite sex, the haploid hyphae may unite a short distance from their points of infection and produce a stout diploid mycelium bearing clamp connections. This actively parasitic mycelium develops abundantly about the point of infection and eventually produces the conspicuous smut galls.

In respect to their life histories, the most interesting point of difference between *U. zeae* and some of the other smuts is to be found, not in the duration of the diploid phase, but in the manner in which it is initiated. The germ tubes from the haploid sporidia of *U. levis* and *U. hordei* are unable to gain entrance to their respective host plants, and it is presumed that infection can be brought about only by diploid sporidia which arise by the conjugation of haploid sporidia of opposite sex. But it has never been shown conclusively that conjugation takes place between the sporidia of *U. zeae*; and, in view of the evidence which has just been presented, this process would appear to be unnecessary. Infection by this fungus is accomplished by germ tubes from the haploid sporidia, and the diploid condition arises almost immediately afterwards by fusion of two haploid hyphae of opposite sex.

Modification of Sexual Reaction by Mutation

It is now well known that prolonged growth on artificial media may bring about very important changes in monosporous cultures of certain heterothallic species. Attention was drawn to this phenomenon first by Kniep (23), who found mycelia with clamp connections and paired nuclei in two monosporous cultures of *Schizophyllum commune* which had been kept for about a year on artificial media. Blakeslee (4) found that (+) and (−) strains of Mucor, when kept in culture for some time, gradually lost their power of uniting with one another. A similar loss of sexual vigor was reported by Couch (10) in Dictyuchus and by Derx (12) in Penicillium.

Bauch (2) states that in young cultures of *Ustilago violacea* the (+) and (–) sporidia can be distinguished readily by their rate of growth on several nutrient substances but that, as the cultures become older, these differences tend to disappear.

It was shown by Christensen and Stakman (8) that cultures of *U. zeae* very frequently produce sectors which differ from their parent colonies in color, type of growth, and certain other characters. Monosporidial cultures of *U. zeae*, likewise, give rise to sectors of this kind. Some of these sectors exhibit very striking morphological variations from the parent cultures, and, although there is no ground for assuming that certain cultural characters are in any way correlated with a particular sexual reaction, the possibility of a sexual mutation during the process of variation is not excluded.

Up to the present, only two of the mutants have been compared with their parent culture in sexual reaction. These mutants appeared in culture A23 growing on potato-dextrose agar, and transfers made from them were grown separately in flasks containing nutrient solution. The resulting cultures of sporidia were mixed in pairs in all possible combinations with the parent culture and the three other monosporidial cultures—A21, A22, and A24—derived from the same chlamydospore. The mixtures of sporidia were then injected into young corn plants in the usual manner. The results

		AB A21	ab A22	AB A23	ab A24	AB A231	AB A232
AB	A21	—	+	—	+	—	—
ab	A22	+	—	+	—	—	—
AB	A23	—	+	—	+	—	—
ab	A24	+	—	+	—	+	+
AB	A231	—	—	—	+	—	—
AB	A232	—	—	—	+	—	—

TABLE 10.—Gall formation in corn plants inoculated with sporidia of *Ustilago zeae*. Cultures of the four sporidia from chlamydospore A2, and two mutants (A231 and A232) from one of these cultures (A23), were used singly and in pairs.

of the inoculations are given in table 10. Both of the mutants—A231 and A232—reacted like the parent with culture A24, but the parent reacted also with culture A22, whereas the two mutants gave a negative result when paired with this culture. It should be noted that the combination A23 ×

A22 produced only a few galls, and it is possible that, under certain conditions, the two mutants, when combined with culture A22, might also have induced the formation of small galls. However, the leaves of infected plants were examined for diploid mycelium bearing clamp connections but none was found. In view of these facts, the most probable interpretation of the results would seem to be that during the process of morphological mutation there occurred also some physiological change which rendered the two mutants incapable of uniting with culture A22.

Aerial Sporidia Produced from Infected Corn Leaves

Under certain conditions cultures of *U. zeae* produce long chains of aerial sporidia. This type of spore production was observed frequently in hanging-drop cultures. Figures of these sporidia have been given by Hitchcock and Norton (20), Clinton (9), and Stakman (33). During the course of the investigations herein recorded, some observations were made which suggest that these aerial sporidia may be produced in nature from infected corn leaves.

Portions of leaves heavily infected with the diploid mycelium of *U. zeae* were floated on distilled water in a petri dish. When, after about 48 hours, the leaves were examined under the microscope, it was found that branches from the mycelium in the epidermal cells had grown upward through the epidermis and produced chains of aerial sporidia. The branches appeared to push through the epidermis at the junctions of the cell walls. Occasionally, the branches bearing sporidia arose from mycelium in the epidermal hairs on the margin of the corn leaf. One of these hairs bearing branches with aerial sporidia is shown in Plate VII, 22.

There seems to be good reason for believing that these aerial sporidia are produced from the diploid mycelium within the host tissue. Stout hyphae, frequently bearing clamp connections, could be seen in the epidermal cells and several of the aerial branches were connected directly with these hyphae. Yet, the aerial sporidia borne on these branches appear to be haploid. When stained preparations were made from a culture of these sporidia, it was found that each cell contained but a single nucleus. Furthermore, six monosporidial cultures were made from them, but when they were injected separately into corn plants they failed to produce galls. It is possible that the aerial branch growing up from a diploid hypha contains a pair of conjugate nuclei and that, when sporidia are formed, some of them receive a nucleus of one sex and others a nucleus of the opposite sex. The manner in which these sporidia are formed requires further investigation.

The separation of two conjugate nuclei which have become associated in a single cell and the subsequent production of haploid sporidia are not

unknown in the smuts. Bauch (3) states that the diploid or fusion sporidia of *U. longissima* which are formed by the conjugation of two haploid sporidia of opposite sex may, in pure culture, produce once more haploid sporidia of the two kinds. Dickinson (13) found this process to occur in cultures of *U. hordei* and *U. levis*. Recently, Dodge (15) showed that the homothallic mycelium of the Ascomycete, *Neurospora tetrasperma*, may produce some unisexual conidia.

In view of the fact that aerial sporidia of *U. zeae* are produced from infected corn leaves under certain conditions in the laboratory, it is possible that this process occurs also in nature. During damp weather, moisture would collect on the infected areas of leaves and stems and there would be provided conditions suitable for the production of these sporidia. Later, when the moisture had evaporated, the sporidia would be carried off by the wind to other plants where they might cause new infections. Such a method of spore formation and dispersal would be important in disseminating the fungus in nature.

Formation of Anthocyan Pigments in Infected Leaves

When the leaves of Golden Bantam corn plants growing in the greenhouse are infected with the diploid mycelium of *U. zeae*, the cells about the infected area take on a bright red color. Apparently, this color formation is characteristic only of leaves infected by diploid mycelium, for it never was observed in leaves inoculated with sporidia of one sex. When portions of a leaf bearing these colored areas are examined under the microscope, it is seen that many of the epidermal cells contain a red coloring matter in solution in the cell sap. Occasionally this red substance separates out in crystals. By crushing a portion of the leaf in a mortar with a little distilled water and filtering off the resulting liquid, it is possible to obtain a clear red solution which changes to a bluish-green on the addition of a drop of alkali. The red color in the leaf apparently is due to an anthocyanin. When a little of the red solution is acidified with sulphuric acid and extracted with amyl alcohol the latter remains almost colorless, indicating that the pigment is in the anthocyanin (glucosidal) condition. By heating some of the acidified solution the anthocyanin is hydrolyzed, and the red material can then be extracted with amyl alcohol. The diploid mycelium evidently does not bring about hydrolysis of the anthocyanin in the infected leaves, but, through its action on the host cells, there results an accumulation of this pigment in the epidermal cells.

SOROSPORIUM REILIANUM

The experiments carried out with *S. reilianum* were of a preliminary nature, but the results obtained seem to be of sufficient interest to war-

rant a brief present mention. The chlamydospores used in the investigation were collected by Dr. H. P. Barss on corn in Oregon.

Spore germination

Fixed and stained preparations for a study of spore germination were obtained by the methods already described for *Ustilago zeae*. The various stages in the germination of the chlamydospores and the budding of the

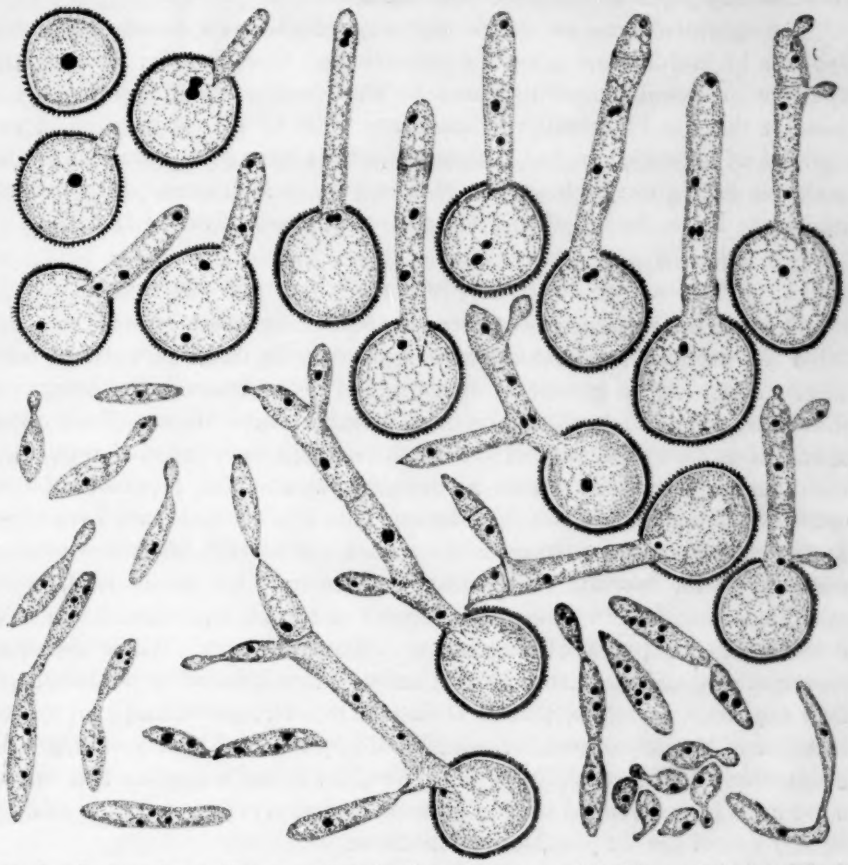

FIG. 3.—*Sorosporium reilianum*. Germination of spores and budding of the sporidia in culture. ×1330.

sporidia are shown in figure 3. The mature chlamydospore contains a single large nucleus. When germination begins, this nucleus divides, and subsequently each daughter nucleus undergoes a second division. Thus there are produced four nuclei, one of which remains in the spore, while the other three are distributed in the promycelium. Cross walls are then

laid down in the promycelium and sporidia are budded off from the promycelial cells. Meanwhile, the nucleus of each promycelial cell has divided and one of the daughter nuclei migrates into the sporidium, the other one remaining in the promycelial cell. In this way, the promycelium is able to produce more than one generation of sporidia. Many irregular forms of germination seem to occur, and frequently one or two promycelial cells may bear mature sporidia before other cells of the same promycelium begin to show any signs of sporidial production.

The sporidia borne on the promycelia and those produced from other sporidia by budding are generally uninucleate. Occasionally, however, the sporidia produced by budding may be binucleate or multinucleate. It is possible that the binucleate condition may arise by the conjugation of two sporidia of opposite sex, but, although sporidia have been found joined together in such a way as to suggest this process, in no instance did a nucleus appear to be in the act of migrating from one sporidium to the other.

Evidence of Heterothallism in Sorosporium reilianum

The four sporidia produced from a single chlamydospore were removed from the promycelium and cultured separately in flasks of nutrient solution. When a good growth of sporidia had been obtained, the monosporidial cultures were mixed in pairs in all possible combinations. Each monosporidial culture and each of the mixtures were then injected separately into young corn plants grown in the greenhouse. The results of the inoculations are given in table 8. The numbers 1 to 4 which have been given to the monosporidial cultures were chosen arbitrarily, since the relative positions of the sporidia on the promycelium were not ascertained.

Plants inoculated with combinations of cultures 1 and 2 and of cultures 3 and 4 produced galls bearing mature chlamydospores. All of the other combinations, and the monosporidial cultures alone, failed to produce galls. It is apparent, therefore, that *S. reilianum* is heterothallic and that a combination of two monosporidial cultures of opposite sex is necessary for the production of chlamydospores. Moreover, the sporidia used in this experiment must have belonged to four different sexual groups, since galls resulted in only two of the six possible combinations.

When corn plants growing in the field become infected with *S. reilianum*, the galls develop in the inflorescence. In this respect *S. reilanum* differs notably from *U. zeae*, for the latter may produce galls in almost any part of the plant. However, the young greenhouse plants infected with *S. reilianum* developed galls only in the leaves, and, although the plants were kept under observation until the time of flowering, no galls appeared in the inflorescences. Leaves bearing galls contained an abundance of stout hyphae

very similar in appearance to those found in leaves infected with the diploid mycelium of *U. zeae*. No hyphae could be found in leaves inoculated with monosporidial cultures of *S. reilianum*, or with those combinations of cultures which failed to produce galls. The red coloration, regularly present in leaves infected with the diploid mycelium of *U. zeae*, was observed also in the leaves bearing galls of *S. reilianum*.

When cultures of *S. reilianum* are grown on potato-dextrose agar, sectors appear frequently at the margins of the colonies. The possibility of a changes in sexual reaction during mutation has not been investigated.

Inoculation of Plants with Mixed Cultures of Ustilago zeae and Sorosporium reilianum

When a single plant is attacked by two species of smuts, or by two distinct races of the same species, opportunities for fusions between neighboring hyphae of the two kinds of mycelia must occur frequently. Fusions of this kind might then be followed by a pairing of nuclei from the two different kinds of mycelia, and this would result, at the time of spore formation, in the production of hybrid chlamydospores. Kniep (26) has shown that conjugation takes place readily between the sporidia of several different smooth-spore species of Ustilago, the (+) sporidia of one species fusing with the (−) sporidia of the other species. Conjugation was observed to take place also between sporidia of different echinulate-spore species, and between those of different reticulate-spore species. Likewise, conjugation occurred between sporidia of smooth-spore species and those of echinulate-spore species, but the pairing of sporidia from reticulate-spore species with those from species having smooth or echinulate spores gave only negative results. Dickinson (14) states that he was unable to infect oat seedlings with sporidia of the two sexes of *U. hordei* but, when sporidia of one sex of *U. hordei* were combined with those of the opposite sex of *U. levis*, infection resulted. The fusion of the two nuclei in the mature chlamydospores must be regarded as the final test of hybridization in the smuts. At the present time there is no record of the experimental production of hybrid chlamydospores.

U. zeae and *S. reilianum* sometimes occur on the same corn plant. As the two species are similar in many respects it seemed possible that under certain conditions they might hybridize. This possibility was tested experimentally by inoculating plants grown in the greenhouse with sporidia of the two species. The following cultures of *U. zeae* were used in the experiment: D11, D13, A11, A12, A13, and A14. These cultures were paired in all possible ways with the four cultures of *S. reilianum*, giving in all 24 mixed cultures. Each pair of cultures was then injected into eight corn

plants. The plants were examined frequently, but in none of them did any galls appear. It is probable, therefore, that hybridization does not take place between *U. zeae* and *S. reilianum*.

DISCUSSION

In considering the results of the preceding experiments it is of interest to compare briefly the relative importance of the parts played by the haploid and the diploid phases in the rôle of parasitism. Plants inoculated with single monosporidial cultures of *U. zeae* and *S. reilianum* apparently were not injured. In the case of *U. zeae*, which was more fully investigated, it was found that the haploid sporidia are able to penetrate the epidermal cells of uninjured corn leaves. But the delicate haploid hyphae seem to lack the vigor necessary for further parasitic development. It is only when two haploid hyphae of opposite sex unite to form a diploid mycelium that the pathogene becomes actively parasitic. Apparently the paired condition of the nuclei is associated with an increase in vigor which enables the invading hyphae to overcome the resistance of the host plant.

In the rusts, active parasitism occurs in both the haploid and the diploid phases. It is a curious fact, however, that, in the smuts, the parasitic habit is confined almost wholly to the diploid phase. The only apparent exception to this rule is to be found in *Doassansia sagittariae*, investigated by Rawitscher; and, in view of the more recent work by Seyfert, it is possible that in this species, too, infection is accomplished by means of haploid sporidia and that the diploid phase arises immediately afterwards by a fusion of two haploid hyphae of opposite sex. Whether or not this loss of parasitism in the haploid phase has been brought about by the habit of saprophytic development which the smuts have adopted would present an interesting subject for speculation.

In heterothallic species such as *U. zeae* and *S. reilianum*, parasitism is very closely linked with sexuality. The immediate result of the initiation of the sexual process is an increase in virulence; but the degree to which virulence is increased depends upon the particular mycelia of opposite sex which have been brought together. For example, a certain culture A, when combined with culture B of opposite sex, may produce relatively few galls but, when united with another culture C of the same sex as culture B, it may become extremely virulent. In the breeding of varieties resistant to these two smuts, therefore, it will be necessary to consider not only the plant's resistance to particular groups of physiologic forms but also its resistance to these forms when combined in various ways.

SUMMARY

1. The behavior of the nuclei during germination of the spores of *Ustilago zeae* and *Sorosporium reilianum* has been described and figured. In both

species the nuclei of the promycelial cells divide at the time the sporidia are formed and a daughter nucleus remains in each promycelial cell. In this way several generations of sporidia may be produced from a single promycelium.

2. Sporidial conjugations have not been observed. The primary sporidia of both species are uninucleate. The secondary sporidia of *U. zeae* produced by budding in culture are also uninucleate, but those of *S. reilianum* are occasionally binucleate or multinucleate.

3. Individual monosporidial cultures of *U. zeae* are able to infect young corn plants but they never produce galls. When a plant is inoculated with two monosporidial cultures of opposite sex, galls are formed which bear mature chlamydospores.

4. Some promycelia of *U. zeae* may bear two sporidia of one sex and two of the opposite sex. Sporidia of the same sex may be arranged in pairs on the promycelium or may alternate with those of the opposite sex. The promycelium of one chlamydospore produced sporidia belonging to four sexual groups.

5. Four monosporidial cultures from an Italian chlamydospore were paired with those from a Minnesota chlamydospore. The same two sexual groups were found to be present in both sets of cultures.

6. Sex in *U. zeae* appears to be determined by at least two pairs of factors. Segregation of these factors may occur at the first or the second division of the chlamydospore nucleus.

7. The haploid mycelium of *U. zeae* consists of fine hyphae and possesses weak parasitic powers. The diploid mycelium, which arises in the host plant by the conjugation of two haploid hyphae of opposite sex, is actively parasitic.

8. Mutants appear frequently in some monosporidial cultures of *U. zeae*. The morphological changes which occur during mutation may be accompanied by changes in sexual behavior.

9. When pieces of corn leaves infected with the diploid mycelium of *U. zeae* are floated on distilled water in a petri dish, hyphae grow out through the epidermis and produce chains of aerial sporidia. These sporidia appear to be haploid. The possible relation of these sporidia to the spread of the fungus in nature is discussed.

10. *Sorosporium reilianum* is heterothallic. Young corn plants inoculated with individual monosporidial cultures never produced galls, but plants inoculated with two monosporidial cultures of opposite sex developed galls containing mature chlamydospores.

11. Sporidia belonging to four sexual groups were produced from a chlamydospore of *S. reilianum*.

12. Mutants appeared in monosporidial cultures of *S. reilianum*.

13. Bright red areas occur in leaves of Golden Bantam sweet corn infected with the diploid mycelium of *U. zeae* or *S. reilianum*. This coloration, which is due to an accumulation of anthocyan pigments in the epidermal cells, was never found in leaves inoculated with a single monosporidial culture.

14. No galls were formed on plants inoculated with mixed cultures of *U. zeae* and *S. reilianum*.

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EXPLANATION OF PLATE VII

The development of *Ustilago zeae*.

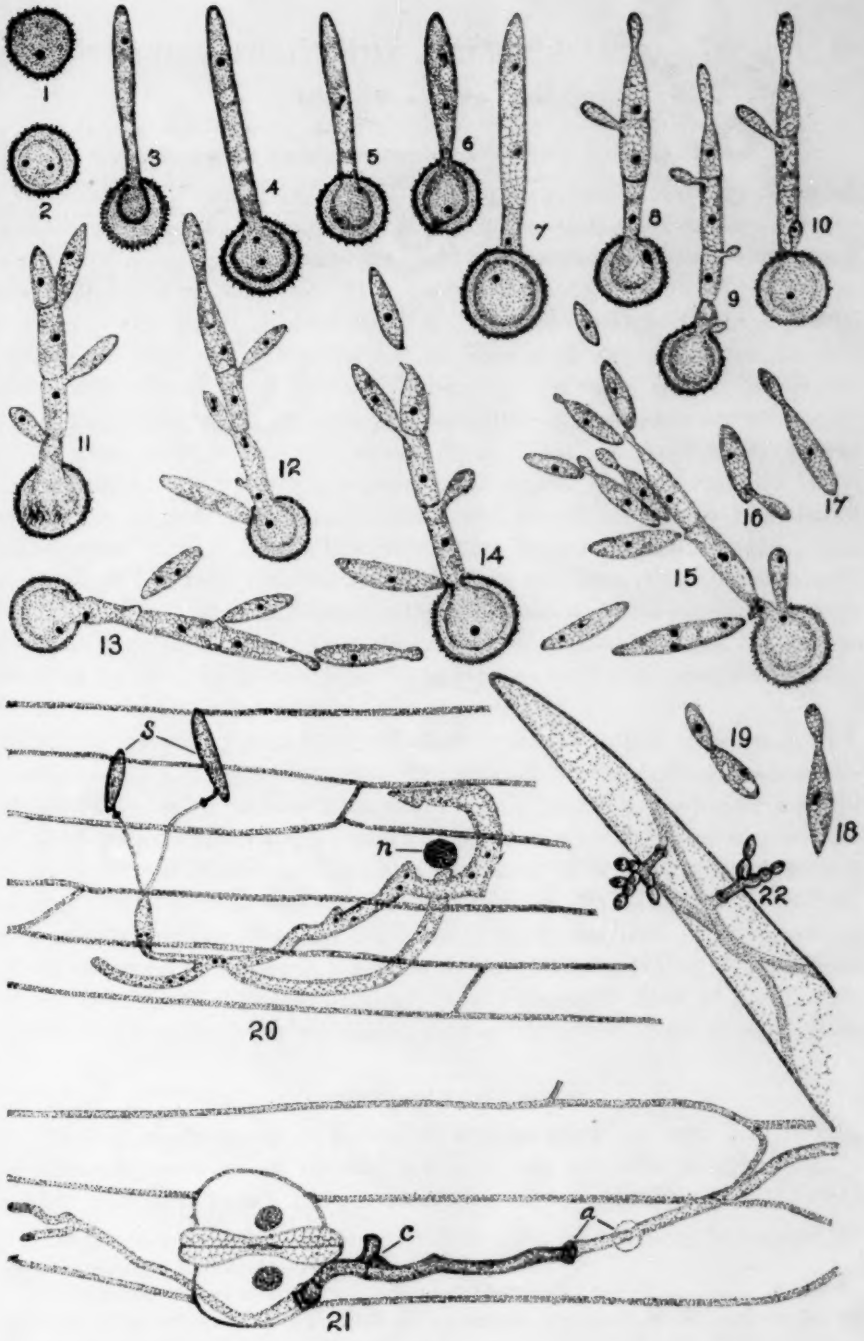
1–15. Spore germination. ×1330.

16–19. The budding of sporidia in culture media. ×1330.

20. Germ tubes from two haploid sporidia (S) of opposite sex penetrated the epidermal cell of a corn leaf and united to form the diploid mycelium. (N) Nucleus of epidermal cell. ×540.

21. Diploid hypha bearing clamp connection (C). The hypha came out through the epidermal cell of the leaf at (A), grew along the surface of the epidermis, and penetrated again beside the stomatal cell. ×540.

22. Mycelium in epidermal hair on margin of corn leaf bearing aerial sporidia. ×600.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SPOROTRICHUM FRUIT SPOT AND SURFACE ROT OF APPLE[1]

MAX W. GARDNER[2]

HISTORY AND OCCURRENCE OF THE DISEASE

In Grimes, Winesap, and Ben Davis apples grown in southern Indiana, a shallow surface spotting or rot, caused by a fungus herein shown to be a strain of *Sporotrichum malorum* Kidd & Beaumont, was found on stored fruit (3).

The disease was first noted by C. E. Baker of the Department of Horticulture, in Grimes fruit taken out of air-cooled storage at the Purdue University orchard near Bedford, Indiana, in February, 1925. Mr. Baker found the disease again the next year in Grimes apples taken out of storage at the same orchard early in March (2, p. 234). In April, 1927, it was found causing heavy losses in a commercial crop of Winesap and Ben Davis apples grown near Seymour, Indiana, and stored in a local commercial cold-storage plant. At the time the writer visited the cold-storage plant, 200 bushels had been restored and 45 bushels had been discarded as worthless, due mainly to this disease, although there was also much secondary invasion of the lesions by blue mold. In 1928, Mr. Baker found the disease showing up as early as November 26 in Grimes apples in air-cooled storage at the Bedford orchard previously mentioned.

In the laboratory numerous isolations from the lesions were made each year and all yielded a slow-growing, grayish brown fungus with which successful inoculations have been made. This fungus proved to be a strain of *Sporotrichum malorum*, a culture of which was obtained for comparison. *S. malorum* was isolated by Kidd and Beaumont (4, p. 111) from rot lesions on apples in storage in England in the winters of 1921–1922 and 1922–1923 and was obtained in 30 out of the 1,795 of their isolations. The symptoms of the Delicious spot disease, a fungus storage rot described by Cunningham (1, p. 185) in New Zealand, rather closely resemble those of the disease under consideration, but no description of the causal fungus was given

SYMPTOMS OF THE DISEASE

On the Grimes apples in air-cooled storage, the spots were 2 to 15 mm. in diameter, more or less circular with a rather indefinite margin, slightly sunken and light brown (amber brown or russet, according to Ridgway's

[1] Contribution from the Department of Botany, Purdue University Agricultural Experiment Station, La Fayette, Indiana.

[2] The writer wishes to acknowledge his indebtedness to Mr. C. E. Baker, of the Department of Horticulture, for his cooperation and to Professor H. S. Jackson for his advice and helpful criticism.

Color Standards) with a light tan (ochraceous-tawny) area at the center, apparently due to the drying of the rotted tissue under the skin at the center of the lesion (Pl. VIII, A, B, C; Pl. IX, B). Frequently, the lesions were numerous on a fruit and by their coalescence involved rather large areas. The lesions were shallow and the rotted tissue was badly disintegrated, shrunken, and either slimy or dried out and punky (Pl. IX, A).

The lesions on the other varieties were essentially similar except that they were somewhat deeper (Pl. IX, A) and, under the more humid conditions in the commercial cold storage, the rotted tissue did not dry out but remained soft and watery (Pl. VIII, D, E). This rotted tissue, together with the skin, sloughed off very easily when the fruit was handled, exposing the sound white tissue not far beneath the surface, and badly affected fruits slipped out of one's hand very easily. On the Ben Davis fruits there was frequently a transverse crack in the skin over the lesion. When affected fruits were held in a damp chamber, there was a scanty development of gray aerial mycelium.

Kidd and Beaumont (4, p. 111), in their brief description, state that the lesions "are dark brown and rather dry and arise at a lenticel spot, insect wound, or at the calyx." The relation to the calyx or insect wounds was not observed on the Indiana apples but many of the lesions were centered about lenticels. Forty-seven lesions on Grimes were examined with this point in mind and 30 were found to be centered about lenticels. On Ben Davis about half of the lesions were so situated but, on Winesap, only 16 out of 101 lesions examined were centered about lenticels.

Ordinarily the lesions were not over 1 or 2 mm. deep although, on the apples in the commercial cold storage, they were about 5 mm. deep (Pl. VIII, E) and, in certain inoculation tests, even deeper lesions occurred (Pl. IX, F, G). The brown rotted tissue was spongy or loose and stringy, much shrunken, sharply delimited, and easily removed from the sound underlying tissue. Microscopic examination of water mounts of the rotted tissue and of razor sections through the lesions showed that the large parenchyma cells under the subepidermal collenchyma were completely collapsed and their walls brown and crumpled but more or less intact. There was an abundance of fine, sparsely branched, colorless mycelium and cylindrical, colorless, one-celled spores between and within the large parenchyma cells (Pl. X, G, H). The epidermal cells and the thick-walled subepidermal cells usually were not collapsed. The collapsed parenchyma cells were readily separated in the water mount and freely floated about, each containing the mycelium and spores of the fungus (Pl. X, G, H) and frequently few or none of the starch grains so conspicuous in the uninvaded cells. The great abundance of the characteristic mycelium and spores in

the rotted tissue, within as well as between the cells, serves as an excellent diagnostic character.

ISOLATION OF THE FUNGUS

Tissue plantings in potato-agar plates were made from 20 lesions on the Grimes apples brought in by Mr. Baker, in 1925, and all yielded apparently pure cultures of the same fungus (Pl. IX, H). Similar plantings were made from 70 lesions on the Grimes fruit in 1926 and all but one yielded the same fungus isolated the year before. Plates were poured from a suspension of the spores in certain of these lesions and were thickly seeded with the same fungus.

Tissue plantings were made from 113 lesions on 16 Ben Davis fruits from the commercial cold storage in 1927, and 75 yielded the same fungus previously isolated, 41 in apparently pure culture. Plantings were likewise made from 58 lesions on four Winesap apples and the same fungus was obtained from 56 and in apparently pure culture from 54. The fungus was isolated also from Grimes apples of the 1928 crop. Furthermore, the fungus has been repeatedly reisolated from apples inoculated in the laboratory.

MORPHOLOGY OF THE FUNGUS

The hyphae are of comparatively small diameter, the young colorless ones averaging about 2 μ in diameter, the older brownish ones about 3 to 4 μ. The hyphae are sparsely branched and form long unbranched strands; the presence of numerous globules gives the contents a beaded appearance. Simple circular loops or coils about 10 to 12 μ across and also coarse, brown, composite strands of about 3 to 10 or more parallel adherent hyphae are produced in the aerial mycelium in culture and in the subepidermal cavities in the lesions (Pl. X, F). The composite strands apparently are the result of the tendency of the successive lateral branches of the parent hyphae to remain adherent and parallel to, but not intertwined with, the parent hyphae. In the condensation moisture about the margin of a hanging-drop culture, the long unbranched hyphae sometimes produce large flat compound coils 20 to 30 μ across (Pl. X, E). Rounded swollen, brown, chlamydospores are found in old cultures.

The conidiophores are short lateral ten-pin-shape hyphae typically about 5 to 8 μ in length and swollen at the center and toward the base. Apparently, the conidiophores may continue to elongate after they begin to produce spores and frequently attain a length of 20 μ (Pl. X, A, B, C). In hanging-drop cultures in prune decoction the conidiophores arise at more or less of a right angle and are usually solitary. (Pl. X, A, C). In the aerial mycelium, however, they arise at a more acute angle and, in the badly rotted host tissues, are frequently in terminal or lateral clusters

or groups, (Pl. X, D), suggestive of Verticillium except that the conidiophores are apparently not in definite whorls. The conidiophores usually are not opposite on the main hypha (Pl. X, B, C) but in the denser clusters are, of course, much more nearly so. In these clusters the lower portion of each conidiophore is often rather closely appressed to the main hypha while the apical portion curves outward.

The spores are colorless, cylindrical or ellipsoidal, one-celled, 4.6 to 8.4 μ in length and 1.4 to 2.1 μ in breadth. The spores are abstricted one after the other from the apex of the conidiophore, each being pushed off by its successor (Pl. X, A, B, C), and in aerial mycelium, or mycelium submerged in agar, accumulate about the tip of the conidiophore in a packet or clump.

CULTURAL CHARACTERS OF THE FUNGUS

The fungus grows readily but rather slowly on the ordinary culture media. In potato-dextrose agar, colonies from spores are white, prostrate, and about 1 mm. in diameter in two days and 9 mm. in 7 days, at about 22° C., with pale, olive buff (Ridgway's Color Standards), cottony, aerial mycelium, on an olive brown to dark olive central area in the substrate and a white border of prostrate radiating hyphae (Pl. IX, K). On older colonies, the aerial mycelium becomes drab gray to smoke gray and the prostrate border may be dark colored (Pl. IX, H). On agar with a lower water content, the aerial mycelium is more velvety and the prostrate marginal zone much narrower. Slant cultures on potato-dextrose agar are soon covered with the grayish aerial mycelium on an olivaceous substrate.

On cornmeal agar, the fungus is prostrate with radiating hyphae and white with the olive brown color appearing at the center much later than on potato dextrose agar and much less pronounced. Cornmeal-agar plates containing large colonies were flooded with an alcohol solution of iodine and evidence of the disappearance of starch under the colonies was obtained. On water agar, containing soluble starch, this test gave more striking evidence that the starch under the colonies had been utilized.

When the fungus was grown on slants of nutrient agar, containing dextrose as a carbon source, and the hydrogen-ion indicators brom thymol blue or brom cresol purple, acid production was indicated by the change to a yellow color. After about 10 days, however, the alkaline color reappeared.

In a test of the effect of temperature on the growth of the fungus on potato dextrose agar, it was found that the average increase in colony diameter in one week was 9 mm. at 12° C., 15 mm. at 17°, 19 mm. at 19°, 22 mm. at 23°, 23 mm. at 27°, 15 mm. at 30°, and 1 mm. at 34°. The maximum radial growth rate is about 1.5 mm. per day. Spores were

produced at all temperatures, and chlamydospores were produced at 30° and 34°. The optimum temperature for growth seems to be between 23° and 27°, but the fungus grows well at lower temperatures and is able therefore to grow slowly in the apples in storage.

The spores germinate promptly in water, prune decoction, and other liquid media, and, on the mycelium thus produced, sporulation is abundant within 3 days. In sterile tap water, germination occurred readily at 12°, 17°, 19°, 23°, 27° and 30° C., and in buffer solutions at hydrogen-ion concentrations from P_H 8.0 to P_H 3.4. Germination was most vigorous at P_H 5.8 to P_H 4.4.

PATHOGENICITY OF THE FUNGUS

The pathogenicity of the fungus was proved by placing slabs from agar plate cultures on the unbroken skin of the apple and also over small scalpel incisions. Inoculations were also made by inserting mycelium or spores into scalpel incisions. On apples thus inoculated and kept 1 to 4 weeks in damp chambers at room temperatures, lesions were found about the incisions, and the presence of the typical mycelium and spores in the invaded tissues together with successful reisolations confirmed the identity of the fungus.

Invasion through the unbroken skin under agar slabs was obtained on fruit of the Grimes, Jonathan, Winesap, Stayman, Rome, Wealthy, Ben Davis, and Gano varieties. The lesions occurred only in the areas covered by the slabs (Pl. IX, C, E) and were usually not over 1 mm. in diameter when the records were taken 1 to 4 weeks later. Many, but not all, were centered around lenticels (Pl. IX, D). Control fruits on which plain agar slabs were placed developed no lesions. Among a total of 31 fruits inoculated, 27 developed these small lesions under the agar slabs. Tissue plantings in agar plates were made from 87 of these lesions and the fungus was cultured from 63. Razor sections through lesions under agar slabs on Grimes fruit, after an incubation period of 10 days, showed the mycelium in the large parenchyma cells of the 13th and 14th cell layers.

Attempts to infect apparently uninjured fruit with a spore suspension prior to storage have been successful and it was found that a very long time was required for the formation of the rather large lesions in storage. On October 12, 1927, 24 Grimes and 12 Stayman fruits were dipped in a spore suspension, held in a damp chamber 24 hours, and then held in paper sacks in cool storage at 15° C. On November 8, no infection was found and the fruit was transferred to a cooler storage room (2° C). On December 15 no lesions were found, but on February 8, one lesion, 12 mm. in diameter and 10 mm. deep, was found on one fruit. There was a cavity under the skin of the lesion due to the shrinkage of the dry spongy or fluffy rotted tissue. This tissue contained an abundance of the spores and the fungus

was reisolated. On March 9, a more or less similar lesion (Pl. IX, F. G) was found on each of six more fruits, from five of which the fungus was reisolated. Twelve fruits of each variety dipped in water instead of the spore suspension and stored under similar conditions to serve as controls remained free from infection.

An additional 12 Grimes fruits, dipped in a spore suspension at the same time, and incubated 24 hours in moist chambers, were stored in sacks in a refrigerator at about 12° C. On February 1, two lesions were found on one fruit and one on a second, ranging from 6 to 10 mm. in diameter and containing the typical spores of the fungus. The fungus was reisolated from each fruit by means of plates poured from a suspension of the spores from the rotted tissues. Twelve fruits dipped in water instead of the spore suspension to serve as checks developed no lesions.

The length of time necessary for the formation of these lesions and the very small size of the lesions in the agar-block inoculations indicate that the lesions found in storage probably develop very slowly. Lesions have never been seen in the orchard nor on recently harvested apples. The Grimes apples on which Mr. Baker found the disease had been carefully inspected by him before they were placed in storage and were found free from all blemishes. Large lesions have been found only after a rather long period of storage. The agar-slab inoculations, however, show that the fungus can infect recently harvested apples, since infection was obtained in September and October as well as later in the storage season. Attempts to infect small green fruits in May were unsuccessful. Just when natural infection occurs and what are the sources of natural infection are not known.

CAUSAL FUNGUS A STRAIN OF SPOROTRICHUM MALORUM

The mode of spore formation indicated that the fungus was probably a species of Sporotrichum, although it showed certain morphological characters in common with Verticillium and Cephalosporium. Cultures of the maple-wilt Verticillium and *Cephalosporium acremonium* were available for comparison. Saccardo (7, p. 870) lists a number of species of these genera on apple wood or fruit, all of which differ in some respect from the fungus under consideration. Among the species described on fruit, *Verticillium lateritium* Berk. differs in color of mycelium and shape of spores (6, p. 156), *V. epimyces* B. & Br. var. *epicarpium* Sacc. in color and shape of spores (6, p. 154), and *Sporotrichum Thuemenii* Sacc. in shape of spores (6, p. 104). In addition to these, Oudemans (5, p. 496), in his list of species on the fruit, includes *Sporotrichum lyococcon* Ehrb., which also differs in shape of spores (6, p. 99).

A culture of *Sporotrichum malorum*, recently described by Kidd and Beaumont (4, p. 111) as the cause of a rot of apples in England, was obtained from the Centraalbureau voor Schimmelcultures at Baarn, Netherlands, and was found to be similar to the Indiana fungus. The two fungi were carefully compared as to morphology, cultural characters, and pathogenicity and, although certain differences were found, these were considered insufficient to warrant the necessity of placing the Indiana fungus in another species.

The two fungi were essentially similar in mycelial characters and in size, shape, and mode of production of the spores. The spores of the Indiana strain were slightly broader and were produced more abundantly in culture. The British strain grew slightly more rapidly in culture, the colonies on the 12th day exceeding in diameter those of the Indiana strain by about 4 mm. There were slight differences in pigmentation. In terms of Ridgway's Color Standards the aerial mycelium of the Indiana strain on potato-dextrose agar was smoke gray and the substrate or under side of the colony was olivaceous black, while the aerial mycelium of the British strain was pale smoke gray and the substrate, dull greenish black. On cornmeal agar, the Indiana strain was darker than the British strain (Pl. IX, J), but the difference was not always so marked as in the colonies illustrated. The two strains were similar in acid production and starch utilization.

Inoculation tests with the British strain were made along with some of those previously described and very similar results were obtained. The lesions produced were similar to those obtained with the Indiana strain both as to effect on the host tissue and the presence of mycelium and spores between and within the cells. Small lesions were formed under slabs from agar-plate cultures placed on the unbroken skin on Grimes, Rome, and Ben Davis fruits (Pl. IX, C) and the fungus was reisolated from 74 out of the 116 lesions tested. The spores were not as numerous in the tissues as in the similar lesions obtained with the Indiana strain.

Out of 12 Grimes fruits, dipped in a spore suspension from the British strain on October 12, 1927, held in moist chambers 24 hours, and then stored in sacks in a refrigerator, five had developed by March 2 one or two rather large lesions, in some instances apparently about wounds. The rotted tissue in the lesions was brownish or dark gray and dry and spongy and contained the typical mycelium and spores. Reisolations were made by the poured-plate method from the spores in six of these lesions, representing each of the infected apples, and practically pure cultures of the fungus were obtained.

Therefore the culture of *Sporotrichum malorum* closely resembled the Indiana fungus in pathogenicity as well as in morphology, and the slight differences in culture are not considered of specific significance. Conse-

quently, it seems justifiable to consider the Indiana fungus as a strain of *Sporotrichum malorum*.

SUMMARY

In Grimes, Winesap, and Ben Davis apples grown in southern Indiana, a shallow surface spotting of fungus origin was found when the fruit was removed from storage.

The lesions were 2 to 15 mm. in diameter, more or less circular with a rather indefinite margin, slightly sunken, and light brown with a light tan area at the center. The lesions were shallow and the rotted tissue, either shrunken and dried out or soft and watery, was easily scraped from the sound white underlying tissue.

The rotted tissues contained an abundance of the mycelium and spores of the causal fungus not only between but also within the large parenchyma cells. These cells were collapsed and separated and many had lost their starch content.

The causal fungus was readily isolated. The hyphae are sparsely branched and frequently form loops or simple coils. In the aerial mycelium compound strands of parallel hyphae are produced. Cylindrical, unicellular, colorless spores are abstricted, one after another, from the tips of unbranched, ten-pin-shape conidiophores.

In the rotted tissues the conidiophores are frequently in terminal or lateral clusters, somewhat suggestive of Verticillium, but the conidiophores are apparently not in definite whorls.

The colonies of the fungus on potato agar have a prostrate margin of radiating hyphae and at the center fluffy, buff or gray, aerial mycelium on an olivaceous substratum. The colony diameter increases at the rate of about 3 mm. per day. The fungus temporarily increases the acidity in dextrose agar and utilizes starch. Best growth occurs between 19° and 27° C. and good growth occurs even at 12° C. The spores germinate readily in a wide range of temperatures and hydrogen-ion concentrations.

The pathogenicity of the fungus was proved by placing slabs from agar plate cultures on the unbroken skin of the fruit and by dipping apples in a spore suspension prior to storage. Infection was obtained on Grimes, Jonathan, Winesap, Stayman, Rome, Wealthy, Ben Davis, and Gano fruits. Infection occurred apparently through the unbroken skin, through lenticels, and through wounds. The fungus was reisolated.

A very long incubation period was necessary for the formation of large lesions. Although the fungus can invade freshly harvested apples, only very small lesions were produced, and large lesions have been found only on apples that have been stored for a rather long period.

A culture of *Sporotrichum malorum*, isolated from apples in England by Kidd and Beaumont, was obtained for comparison and in morphology, cultural characters, and pathogenicity to apples proved to be so like the Indiana fungus that the latter is considered a strain of that species. The British strain differed mainly in its slightly faster growth, lighter pigmentation on cornmeal agar, and less profuse sporulation in culture. The lesions which it produced on apples were very similar to those produced by the Indiana strain as was also its effect on the host tissues.

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EXPLANATION OF PLATES

PLATE VIII

A. Sporotrichum lesions on Grimes apple taken out of air-cooled storage early in March, 1926.

B and C. Sporotrichum lesions on Grimes apples taken out of air-cooled storage in February, 1925.

D. Advanced stages of Sporotrichum surface rot on Ben Davis apple taken from commercial cold storage in April, 1927. Rotted tissues, soft and watery.

E. Cross section of a Ben Davis apple in commercial cold storage showing shallow penetration of the surface lesions.

PLATE IX

A. Sporotrichum lesions on Winesap apple in commercial cold storage, April, 1927. Skin shaved off to show appearance of rotted tissues.

B. Small Sporotrichum lesions on Grimes apple from air-cooled storage, 1926, enlarged to show the light center and indefinite margin.

C. Lesions on Grimes apple inoculated by placing a slab from an agar culture of the British strain on the unbroken skin. ×2.

D. Lenticel lesions on Stayman apple inoculated 12 days previously (February 1, 1926) by placing slab from agar culture of the Indiana strain on the unbroken skin. ×6.

E. Lenticel lesions on Grimes apple inoculated 12 days previously (February 1, 1926) by placing slab from agar culture of the Indiana strain on the unbroken skin. ×2.

F and G. Sections through large deep lesions on Grimes fruits inoculated by dipping in a spore suspension in October and held in cold storage until March.

H. Sporotrichum colonies from tissue plantings in potato-dextrose agar. Isolations from lesions on Grimes apples, February, 1925.

J. Difference in rate of growth and pigmentation of 13-day-old colonies of the Indiana (above) and British strains on cornmeal agar. The British strain produces less pigment on this medium and grows slightly faster.

K. Six-day-old colonies from spores in a poured plate of potato-dextrose agar.

PLATE X

A to C. Conidiophores and conidia in condensation moisture about the margin of hanging-drop cultures in prune decoction. Indiana strain. Cultures 5 days old. ×850.

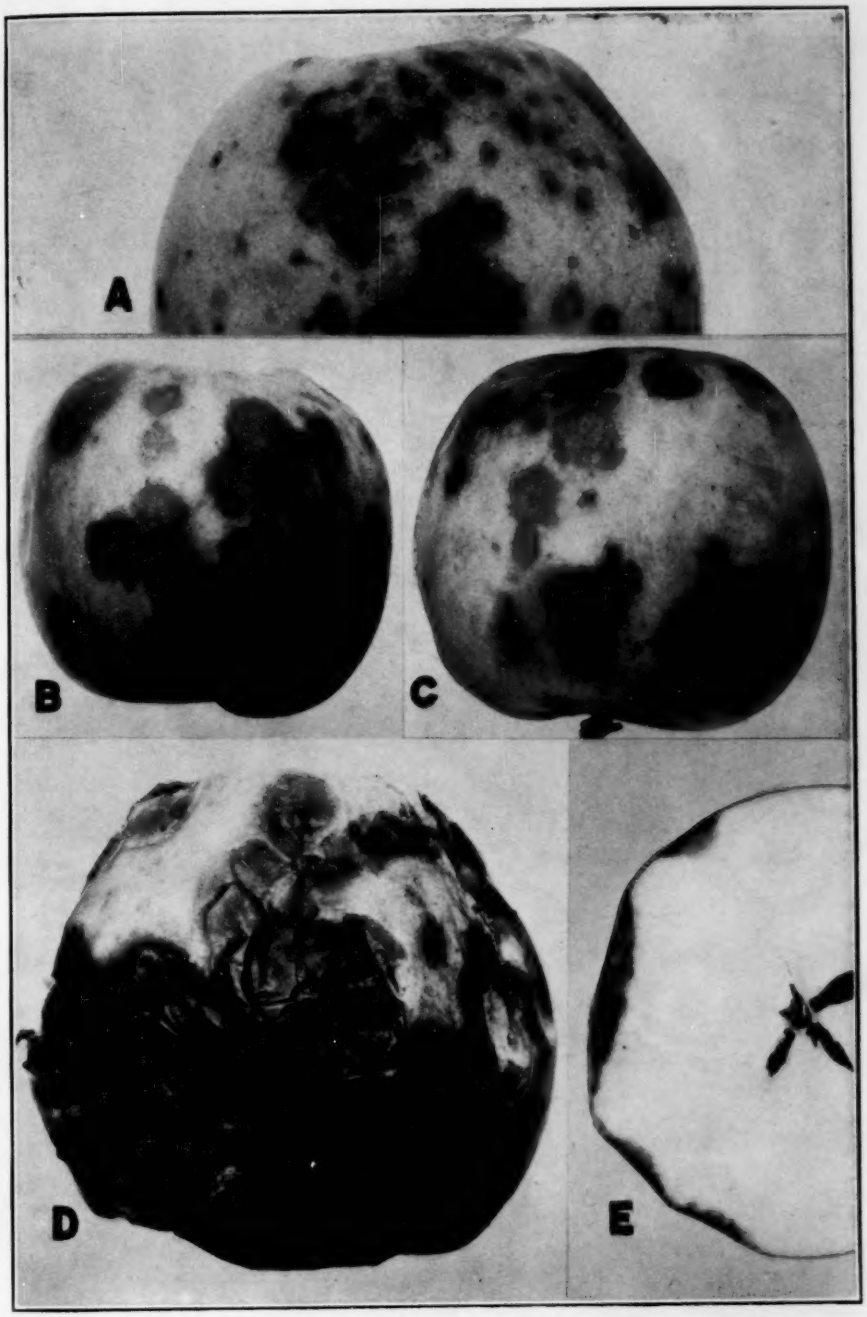
D. Conidiophore clusters produced in rotted tissue. The central cluster is from an apple inoculated with the British strain as described below under G. (×600.) The other two clusters are from naturally infected apples. (×750.)

E. Compound hyphal coil in condensation moisture about the margin of hanging-drop cultures in prune decoction, 6 days old. Indiana strain. ×850.

F. Composite strand consisting of numerous parallel hyphae. From aerial mycelium on culture of Indiana strain. (×750.)

G. Portion of a parenchyma cell in a water mount of rotted tissue from a lesion on a Grimes apple showing the numerous spores within the cell. The fruit was inoculated in October by dipping it in a spore suspension from the British strain and removed from storage in March. ×675.

H. Portion of a parenchyma cell in a water mount of rotted tissue from a lesion on a Grimes apple showing the mycelium within the cell. Fruit inoculated as noted above in G. ×425.



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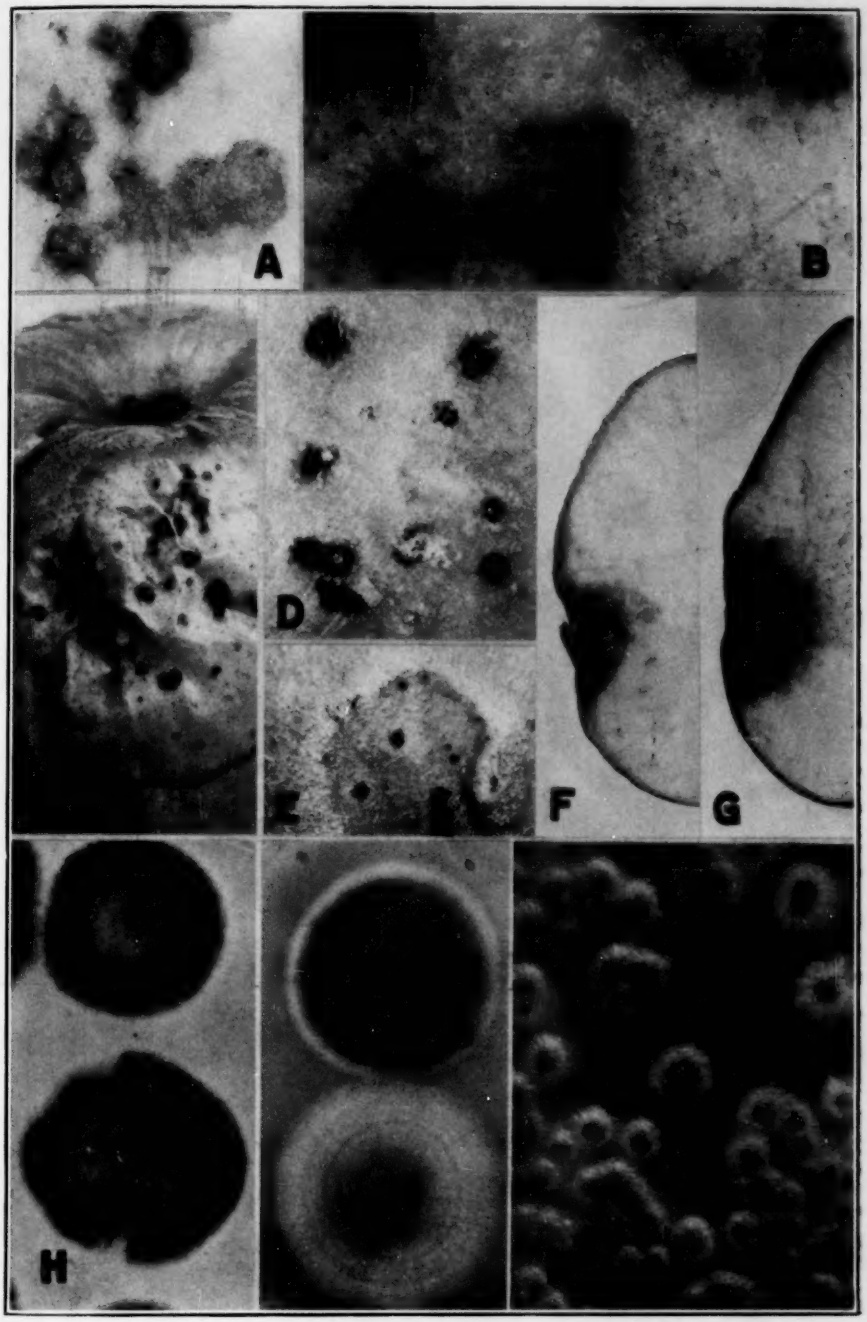
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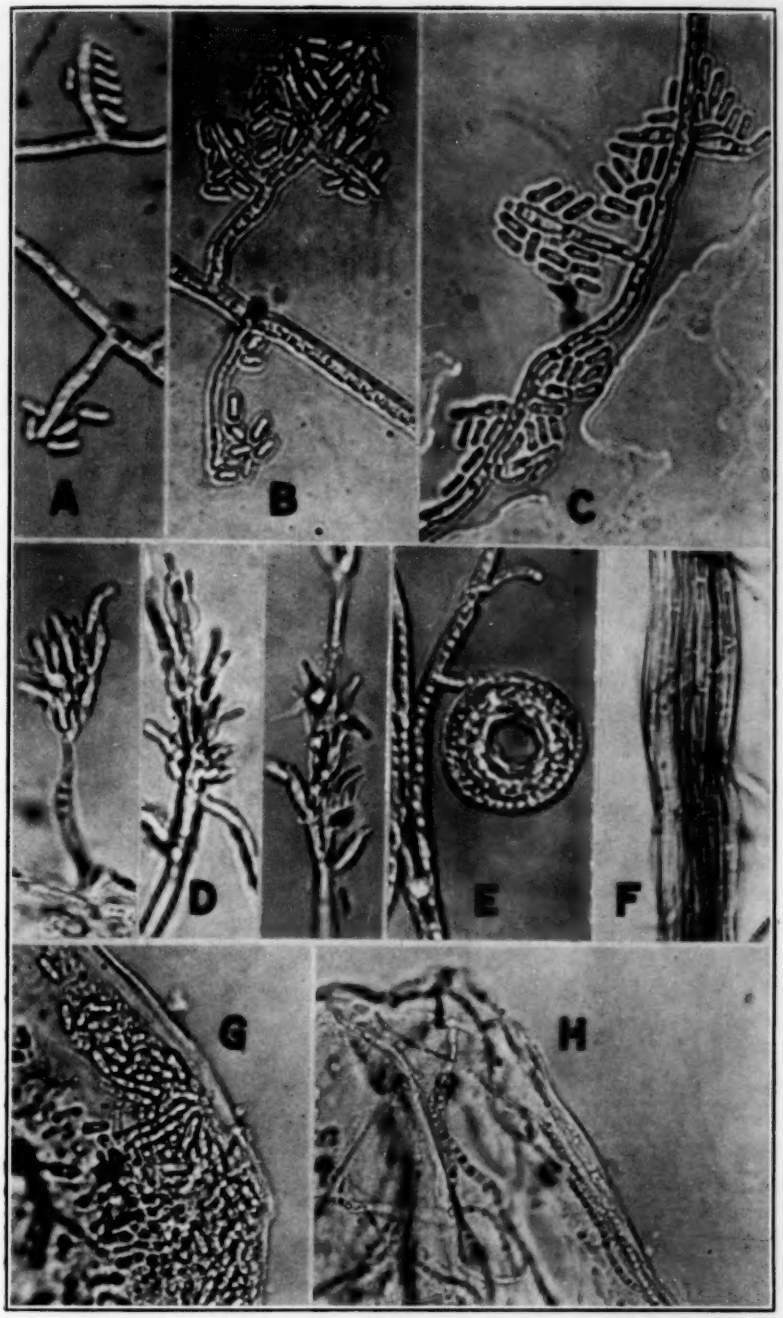
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CRONARTIUM COMPTONIAE ARTH. IN WESTERN NORTH AMERICA

H. G. LACHMUND

INTRODUCTION

Cronartium comptoniae Arth., a serious blister rust of pitch and hard pines, alternating to members of the family Myricaceae, has been known in North America since 1906, when it was named by Arthur (1). Connection of the uredinial and aecial stages was established by Clinton in 1907. Subsequent work by various investigators (4 to 10, 12, 13, and 15 to 20) showed the disease to be indigenous, ranging from New Hampshire south to North Carolina and west to Minnesota and Missouri. The disease is characterized as very harmful to young pines both in the nursery and in the forest and especially destructive to introduced western pines (15). The need for keeping it out of the Pacific Northwest where the range of the alternate host, sweet gale (*Myrica gale* L.), was known to overlap portions of the commercial ranges of western yellow pine (*Pinus ponderosa* Laws.) and lodgepole pine (*P. contorta* Loudon) was emphatically pointed out by Rhoads and others (15) in 1917. The importance of these species, particularly of western yellow pine, in this section, together with the evidence of their susceptibility developed in the East, fully justified this warning. Botanical exploration of the Pacific Northwest had not then been sufficiently intensive to provide details on the extent of association of sweet gale with pines. The purpose of this paper is to report the discovery of this disease and the results of subsequent study of it in this territory. The rust is indigenous here as well as in the East.

WESTERN DISCOVERY, DISTRIBUTION, AND HOSTS

Credit for the discovery goes to Mr. H. N. Putnam of the Office of Blister-Rust Control and to Dr. J. S. Boyce of the Office of Forest Pathology, who first noticed the disease on sweet gale (*Myrica gale*) at Daisy Lake, British Columbia, on October 13, 1924. Telial material was collected and sent for determination to Spaulding who identified it tentatively as *Cronartium comptoniae*. On May 5, 1925, the writer collected aecial material showing the characteristic tooth-like margins along the dehiscence of the peridia from *Pinus contorta* in the vicinity of the sweet gale at Daisy Lake. Part of this material was sent for further examination and use in cross inoculations to Spaulding who, with suitable precautions, successfully infected *Myrica asplenifolia* L. (*Comptonia peregrina* L. Coulter) with it, and definitely established its identity as *Cronartium comptoniae*. Since discovery of the rust at Daisy Lake, knowledge of its western distribution has

been extended to include records of it from a number of widely separated localities, the northernmost of which to date has been Prince Rupert, British Columbia, and the southernmost located at Ilwaco, Washington, at the mouth of the Columbia River. Infection was found on pine and sweet gale at both of these limits.

In the East, the hosts listed (15) for the aecial and pycnial stages are the following species of Pinus: *banksiana, contorta, densiflora, echinata, jeffreyi, maritima, montana, mugho, nigra austriaca, ponderosa, pungens, resinosa, rigida, sylvestris, taeda,* and *virginiana;* and for the uredinial and telial stages: *Myrica asplenifolia* (*Comptonia peregrina*), *M. gale,* and *M. carolinensis.* In the West, the rust has been found on lodgepole pine and sweet gale, only. No associations of sweet gale with other susceptible pine species have yet been recorded. Within the range of the rust here, sweet gale is a plant of very local occurrence, limited to certain types of swampy ground in bogs and along lake margins. South of British Columbia, it is uncommon. The vegetation with which it commonly is associated and its habitat render it both inconspicuous and inaccessible. The aecial host, lodgepole pine, is inferior among Pacific Coast timber trees. Its diseases have received relatively little attention. Furthermore, detection of the disease on it is complicated by the similarity in appearance of another closely related, much more common and widely distributed, native rust of the same host, *Cronartium filamentosum* (Peck) Hedgc. & Long. These conditions, added to the fact that the Pacific Northwest is comparatively new territory in mycological exploration, readily explain why the disease was not discovered earlier.

The complete distribution of the disease as now known is shown in figure 1. Localities in which it has been found on the uredinial and aecial hosts are indicated by dots and triangles, respectively. The altitudinal range of these localities in British Columbia, for both pine and sweet-gale infection, extends from sea level to 1400 feet. Ilwaco, Washington, the only recorded locality of occurrence south of the International Boundary, is at sea level.

CHARACTER OF INFECTION AND DAMAGE

On sweet gale, the rust causes a characteristic spotting of the leaves. The yellowish uredinia on the dorsal surface are soon followed by telia. The brownish telial spore horns develop in dense, more or less matted, tufts and are produced in abundance. Even with quite heavy infection, little injury is evident on this host.

Infection of the pines, as in the East (18, 13), takes place only on the youngest seedlings. Apparently, it occurs very sparingly, if at all, on trees

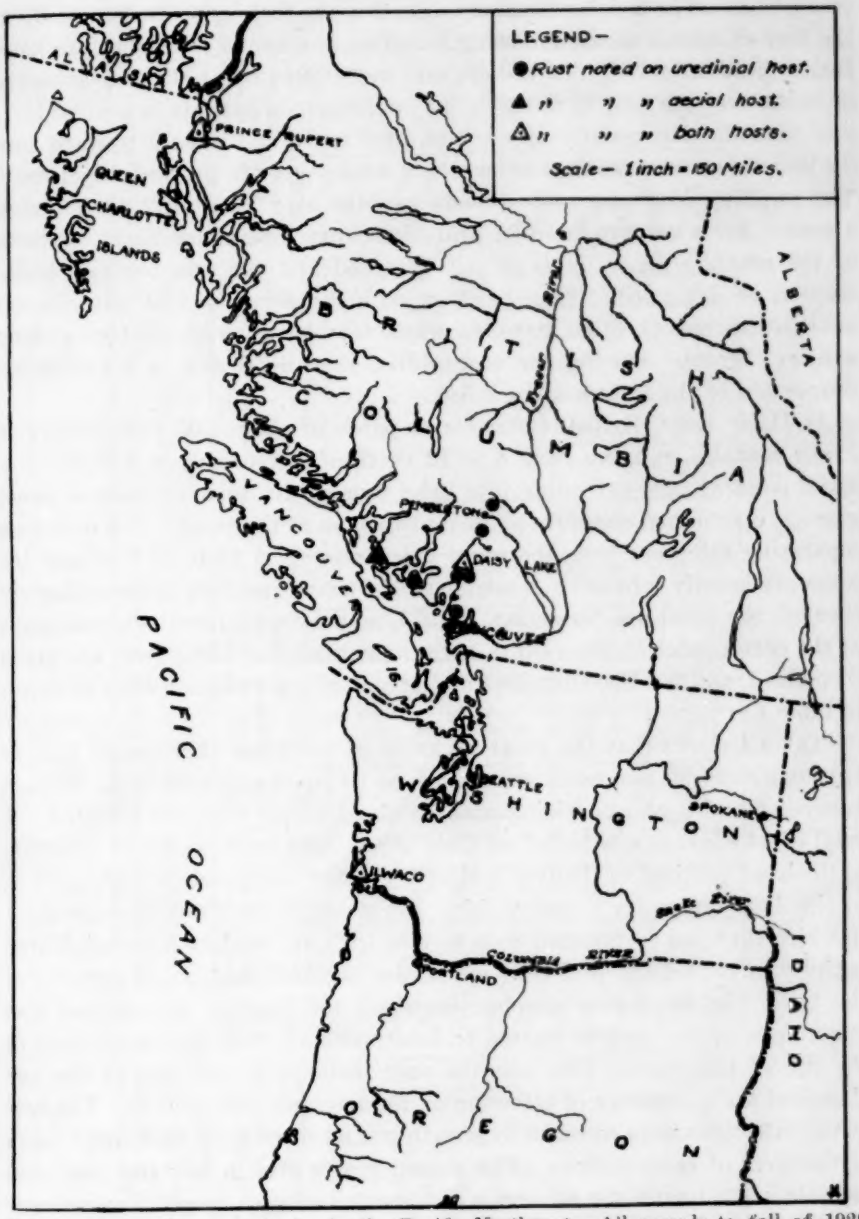

FIG. 1. *Cronartium comptoniae* in the Pacific Northwest. All records to fall of 1928.

more than 10 or 12 years of age and only the basal portions of the tree are susceptible. The incipient cankers seem to make their appearance mainly in the first or second season following infection and rapidly develop into long, fusiform swellings. Since the cankers are almost invariably on branches or stems near the base of the tree, the swelling soon spreads to ground level and the infection usually appears to start there and extend upward into the lower branches. In the earlier stages, canker growth proceeds vigorously. The swelling increases and spreads rapidly at a rate of 2 to 6 inches a year. Aecia are produced in profusion from the swollen bark. Growth of the seedling generally is greatly retarded and the tree becomes badly stunted or deformed. This, together with the formation of pathological adventitious shoots, often gives the whole seedling the character of a short witches' broom. During the susceptible, juvenile period, a considerable proportion of the trees may be killed.

At Daisy Lake, British Columbia, a patch of about 500 young trees of *Pinus contorta*, ranging from 4 to 12 years of age, occurs on a knoll on a small point of land extending into Lake Lucile. Numerous plants of sweet gale are distributed along the shore on two sides of the point. The distances separating the pines from the sweet gale range from 15 to 50 feet and the pines are heavily infected. A sample of 134 trees examined indiscriminately through the patch on November 1, 1925, may be considered representative of the entire patch.[1] The results of the examination of these trees are given in tables 1 and 2. The character and extent of the infection here is shown in table 1.

Table 1 shows that the great majority of the trees (127 out of 134, or approximately 95 per cent) are from 5 to 10 years old, with most of them between 6 and 8 years. Eighty-nine, or about 65 per cent, are infected. A total of 94 cankers was found on these trees. The confinement of infection to the basal portions of the tree is clearly evident. Apparently, only growth of the first four years is susceptible. For example, in the 5-year-age-class, in which the trees germinated from seed in 1921, the cankers have originated entirely in 1921, 1922, and 1923 internodes, the first three years' growth of the trees. In the 6-year-age-class in which the year of germination was 1920, three of the cankers started on internodes of 1923, the fourth year in the life of this class. This was the only instance in any one of the age classes of the occurrence of infection on the fourth year's growth. The rest of the infections were confined to growth put on during the first three years of the lives of the seedlings. The second year's growth was the most susceptible. The figures for cankers which started on such growth are inclosed by the diagonal lines in table 1. Of the total of 94 cankers, 54 started in such growth.

[1] Observations at other places indicate that the infection at Daisy Lake is typical.

TABLE 1.—*Growth affected by Cronartium comptoniae Arth. on Pinus contorta Loudon, Lake Lucile, Daisy Lake, B. C., November 1, 1935*
Analysis of 92 infections on 87 infected plants found in a total of 134 taken as a sample from a heavily infected patch of about 500 young pines

Age of seedling (Years)	Year germinated	Number of seedlings		Percentage infected	Number of cankers																		
					Of all ages										Young alone								
					Year's internode in which canker originated										Year's internode in which canker originated								
		Total	Infected		'25	24	'23	'22	'21	'20	'19	'18	'17	'16	Total	'25	'24	'23	'22	'21	'20	'19	'18	'17	Total
3	1923	0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4	1922	2	2	100	0	0	1	1	—	—	—	—	—	—	2	0	0	0	0	—	—	—	—	—	0
5	1921	13	7	54	0	0	1	3	3	—	—	—	—	—	7	0	0	0	0	0	—	—	—	—	0
6	1920	30	23	77	0	0	3	3	15	5	—	—	—	—	26	0	0	3	1	0	1	—	—	—	5
7	1919	32	23	72	0	0	0	0	5	17	2	—	—	—	24	0	0	0	0	1	1	1	—	—	3
8	1918	24	15	62	0	0	0	0	0	5	10	0	—	—	15	0	0	0	0	0	2	2	0	—	4
9	1917	17	12	71	0	0	0	0	0	0	7	6	0	—	13	0	0	0	0	0	0	0	1	0	1
10	1916	11	7	64	0	0	0	0	0	0	0	5	2	0	7	0	0	0	0	0	0	0	2	0	2
11	1915	3	—	—	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	1914	2	—	—	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	1913	0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total		134	89	66.4	0	0	5	7	23	27	19	11	2	0	94	0	0	3	1	1	4	3	3	0	15

Most of the cankers were well developed and had produced aecia more than once. It was clear that the large majority of them had been in existence for some years. Fifteen of the 94 cankers, however, were in the incipient or early stages of development and of relatively late origin. The occurrence of these young cankers is shown in the right-hand section of table 1. It will be noted that they are not confined to the youngest trees. They are, in fact, more or less generally distributed irrespective of age class.

As just stated, these cankers were all of a class in stage of development. There could have been hardly more than a year's difference in age. Three occurred on 1923 growth, and very probably originated that year, since an assumption of infection in 1924 would allow a very short period for incubation. The year 1923, therefore, marks the probable beginning date of all of the young cankers, although it is possible that a few originated from infection in 1922. Assumption of earlier years of origin is possible for cankers of this group on growth of earlier origin than 1922, but this would be stretching the incubation period beyond the limits of probability. Turning again to the left-hand section of table 1, reference to columns 10, 11, and 12 shows the majority of all the cankers, most of them relatively old and in well-advanced stages of developemnt, to be located on 1921-, 1920-, and 1919-growth. None of this majority could have originated prior to 1919, the largest share could not have originated prior to 1920, and 23 could not have originated prior to 1921. This, in general, indicates a relatively short incubation period.

The occurrence of young cankers on some of the oldest trees is therefore interesting, in view of the limitation of infection to the first four years' growth. It indicates that this growth continues to remain susceptible for a period of several years, while the nodes and internodes of more recent development, immediately adjacent on the same tree, are immune. This seems so odd a circumstance that the writer is inclined to question whether further investigations and a larger basis of observations will not show some susceptibility in nodes and internodes produced at least a few years subsequent to the fourth year in the life of the tree.

The degree and extent to which the growth of the first four years retains its susceptibility can not be read clearly from the present data. Obviously, the length of the period of susceptibility will depend, in large measure, on how infection takes place. The mode of infection is not known for *C. comptoniae*. It might be directly through the bark, through the needles, or both. In the first case, thickening and hardening of the outer bark would, probably, very soon prevent any penetration by the germ tubes of the delicate sporidia. In case infection occurs through the needles, the period of susceptibility might be longer. Young lodgepole pine retains a season's growth of needles commonly seven or eight and sometimes as many

as nine years. The opportunities for infection through this channel might remain at their maximum for 4 or 5 years. With the commencement of defoliation the possibility of infection would obviously decline and, on complete defoliation, a season's growth would be immune. With susceptibility limited to the growth of the first four years, the trees would become immune when the last needles dropped from the fourth year's growth, or, at the latest, in the thirteenth year of the life of the tree.

The figures for the occurrence of the young cankers, given in the right-hand section of table 1, show that susceptibility may persist for a number of years. Confining attention to the classes with the most substantial bases, i.e., the 5- to 10-year-age-classes, something of the degree of susceptibility during this time may be gathered from the figures on the percentage of infected trees per age class.

To interpret these figures, one should know approximately the year in which the disease first invaded the patch. The oldest growth on which cankers had originated anywhere in the entire infection area was that of 1917. The disease therefore did not enter prior to 1917. It is barely possible that it may have entered in 1917 or 1918. In this case, however, since trees of the 1914, 1915, and 1916 generations were present, it would be very difficult to explain the absence of cankers on wood grown in 1914 to 1916. Furthermore, the most advanced cankers on growth put on in 1917 and 1918 were entirely similar in stage of development to those in the most advanced stages on growth made in 1919 and 1920. Together, they form an approximately equal-age group representing the oldest infection on the area. Assuming that they were of exactly equal age, it would be obvious, since some of them occurred on growth made in 1920, that none of them could have originated from infection earlier than 1920. Allowing a year for age variation, part of them might have originated from infection in 1919. Comparison with the younger age classes of cankers made it plain that the large majority originated prior to 1921. The first infection of the pines, then, evidently must have occurred either in 1919 or 1920.

Assuming that the disease first became established in the patch six years before, or in 1919, trees in the 5- and 6-year-age-classes were then nonexistent. They must have become infected in later waves of inoculation. Trees in the 7-year-age-class were in their first year of growth. Those in the 8-year-age-class were in their second year. Obviously, being larger, they must have offered a larger inoculation target than did those in the 7-year-age-class and, so on, to the 10-year-age-class. With susceptibility limited to the first four-years' growth, the trees in this latter class, being in their fourth year, were then virtually at their maximum target size. They should normally have remained quite unchanged in this respect through the entire period of years in which the cankers originated, or from 1919 to 1924. If

the mode of infection is through the needles, there would have been some reduction of target in this age-class by the end of 1924, because of defoliation of the first two-years' growth. But the third- and fourth-year internodes were still only seven and six years old, respectively, and normally should still have had full quotas of needles, good for another season at least. Thus during the period of infection, 1919 to 1924, in the 5- to 10-year-classes, defoliation may be considered of negligible influence upon the chances for infection, and it is obvious that exposure to infection, both in degree and duration, must have been very much greater in the older than in the younger trees of these classes. On this basis, the percentage of trees infected and the number of cankers per tree should show a very decided increase in the older classes. The fact that there is no such increase is evidence of a rapid reduction in susceptibility considerably in advance of defoliation of the susceptible parts. Whether or not this indicates infection through the bark and resistance to be the result of early thickening and hardening of the outer layers or whether it indicates early development of resistance in the needles, can not be stated.

The extent of damage caused by the infection just described is evident in table 2.

Of the 134 trees, approximately 7, 4, and 13 per cent, respectively, are killed, dying, and badly stunted and deformed. Taken as percentages of the infected trees, these figures become approximately 10, 6, and 19. In the column headed "killed" the trees are entered in their proper age class. Although most of these trees died in the year of the examination, one or two had succumbed the year before. The age at death was, therefore, a little younger in several cases than indicated. It is evident from this column and from the data on the dying trees and on those that are badly stunted and deformed that the susceptibility to damage is highest in the youngest age classes and that it decreases rapidly with increasing age of the tree. Apparently the disease is not destructive of trees beyond the ages of 8 or 9 years.

If the seedling survives this early period of susceptibility, it rapidly develops further resistance to the effects of the disease, the disease is more or less completely overcome, and the external evidences of its presence largely disappear. Aecial production stops entirely and the only symptoms may be the remains of the witches' broom or killed leader of the original seedling at the base of the tree, more or less calloused over and enveloped or extruded in the subsequent growth, together with perhaps some evident abnormal swelling near the root collar. In some cases the swelling may extend irregularly up the bole for some distance, apparently indicating that the mycelium is still active in the bark of the slow-growing trees thus affected. At a place about 4 miles north of the

TABLE 2.—*Effects of Cronartium comptoniae Arth. on 134 plants of Pinus contorta Loud. selected as a sample lot from a heavily infected patch of about 500 young trees at Lake Lucile, Daisy Lake, British Columbia, Nov. 1, 1925*

Age of seedlings (Years)	Number of trees Basis	Infected		Killed		Dying		Others badly stunted and deformed	
		Number	Percentage	Number	Percentage of number infected	Number	Percentage of number infected	Number	Percentage of number infected
4	2	2	100.00	1	50.00	—	——	1	50.00
5	13	7	54.00	3	42.80	1	14.30	1	14.30
6	30	23	77.00	3	13.05	3	13.04	7	30.40
7	32	23	72.00	1	4.35	1	4.35	6	26.04
8	24	15	62.00	1	6.66	—	——	1	6.66
9	17	12	71.00	—	——	—	——	1	8.33
10	11	7	64.00	—	——	—	——	—	——
11	3	—	——	—	——	—	——	—	——
12	2	—	——	—	——	—	——	—	——
Total	134	89	66.40	9	10.10	5	5.62	17	19.10
Percentage of the total basis					6.72		3.73		12.68

infection center at Lake Lucile, within 100 to 150 feet of large thickets of *Myrica gale* found well infected with the rust on October 24, 1925, four trees were found which bore striking evidence of the capacity of *Pinus contorta* to overcome the attack. These trees were 22, 24, 35, and 37 years of age. In the presence of the old, dead witches' brooms and killed parts of the original seedlings at their bases, all bore distinct evidence of earlier infection by *Cronartium comptoniae*. There was nothing else in that section which could very well have caused such symptoms and the situation of the trees with respect to the sweet gale and the presence of two younger trees, 9 and 14 years old, in the early stages of recovery from the disease, left little room for doubt as to the diagonsis. The effects of the disease in two of the four trees were practically negligible. In the other two, growth was slower than normal and on the lower bole of one of these the irregular swelling just mentioned was conspicuous.

The evidence of infection on these trees indicated that the rust had been present in this locality some thirty years or more. No doubt some of the other trees of similar age and possibly others of still greater age in the locality, which now show no evidence of the disease, had undergone a similar juvenile attack.

PRODUCTION OF FRUITING STAGES AND METHOD OF SPREAD

On the youngest trees where *Cronartium comptoniae* is in full activity, aecial sporulation occurs mainly in the spring during late April and May. Production of a few small aecia may occur also in late fall, depending upon the character of the season. This seems to be a rather common occurrence with Cronartium in the Pacific Northwest. The writer has noted it regularly with *C. ribicola* in this territory as well as in several instances with *C. filamentosum*. The uredinial stage appears on *Myrica gale* usually in June and July, the telial stage following in abundance in August and to the dropping of the leaves.

So far, the disease has been found wherever sweet gale has been examined in the fall. In most places trees of *Pinus contorta* have occurred in the immediate or near vicinity and the rust has been transmitted to the neighboring sweet gale from them. In a number of localities, however, this is not the case. Nevertheless, infection of the sweet gale in those localities has been plentiful in the fall.

The presence of the rust in these cases and its general occurrence in all the scattered places in which sweet gale has been found seem to indicate, as with *Cronartium ribicola* in the West (14, 11), that this rust may spread great distances from the aecial to the uredinial hosts. Other possible methods of spread are eliminated through lack of any affirmative indications. Among the possibilities may be considered the same factors that have been

considered in arguments for the method of spread of *C. ribicola*, such as (1) overwintering of the rust in the uredinial stage and spread by urediniospores, (2) direct transmission of infection from pine to pine by means of aeciospores, and (3) spread by means of sporidia. With respect to overwintering in the uredinial stage, there is not the least evidence that this occurs in the Pacific Northwest. *Myrica gale* loses its leaves entirely each fall and evidently the rust goes with them. No signs of infection on other parts of the plant, such as the shoots and buds, which might carry the disease over the winter, have been noted. And even where sporulating aecia have been situated in immediate proximity to the sweet gale, it has not been until well past full leaf development that the first signs of uredinial infection have been observed to make their appearance in the following spring.

With respect to the possibility of direct aecial spread or of wide spread by means of sporidia, the rust on pines has been invariably found only within very limited radii of the sweet gale. Heavy pine infection in the immediate vicinity of the latter host rapidly gives way to sparse and light infection as the distance from the sweet gale increases, and beyond a distance of two- or three-hundred yards becomes negligible. The concentration of pine infection within such short distances of the uredinial host argues quite evidently against any supposition of direct aecial spread or long-distance spread by sporidia to explain the extent and characteristics of the distribution noted. It is possible that birds and insects may have played a considerable part in distributing the disease either by dissemination of aeciospores or urediniospores, although there seems to be nothing particularly attractive to either of these classes of potential spore carriers about either of the hosts. This seems especially to obtain with the sweet gale which has shown little or no evidence of insect attacks and is apparently little frequented by birds.

Another possibility may be that of wind dissemination of the urediniospores. Urediniospore production, however, is light as compared with the production of aeciospores which are carried away in clouds at the least jar of the infected pines during sporulation in the spring, and all indications seem to suggest rather that wide dispersal of the rust is accomplished mainly by wind dissemination of the aeciospores.

The disease has been found quite to the southern limit of occurrence of the uredinial host. The sweet gale ranges north into Alaska, east to Labrador, and south into the known range of the rust in the East. Susceptible pine hosts are distributed transcontinentally over the same territory. It is probable therefore that the rust spans the continent on the north and that its eastern and western ranges are connected.

No associations of *Myrica gale* with *Pinus ponderosa*, the most important timber tree of all the western hard and pitch pines, have yet been noted

within the natural range of this pine. Consequently, no occurrence of the disease within this range has yet been recorded. With evidence that it is highly susceptible, however, (13) and in view of the indications of the rust's capacity for long-distance spread it may be expected that infection will be found on it here, also, where such associations occur. On the other hand, observations made to date, together with distribution data from various floras, indicate that these associations are rare, if they exist at all. Consequently the rust can not be considered a serious threat to western yellow pine within the native range of this tree.

It was at first thought possible that *Myrica californica* Cham. & Sch. might be a factor in carrying the rust southward from the southern limits of *M. gale* into the southern Oregon and California pitch- and hard-pine regions. While this species of Myrica had been shown by inoculations in the East (20) to be immune from the disease, and scouting for the rust on it in California by Meinecke and his associates had resulted negatively, there still was some question as to whether, under natural conditions, it might not become infected. Opportunity to check up on this was afforded at Ilwaco, Washington, near the southern limits of the occurrence of *M. gale*. The disease was found here on *M. gale* and *Pinus contorta* in the immediate vicinity of *M. californica*. The latter showed no sign of uredinia or telia and it may be concluded that this species, as indicated by the results of eastern inoculations and of previous western scouting, will be of no significance in the rust's distribution.

SUMMARY

An account is given of the discovery of the rust disease caused by *Cronartium comptoniae* in the Pacific Northwest. Its range includes the section west of the Cascade Mountains from Ilwaco, Washington, north to Prince Rupert, British Columbia. The disease is indigenous here, as in the East. The only known uredinial host of the rust within this range is *Myrica gale*. The aecial stage has been found only on *Pinus contorta*.

The uredinial host is a plant of very scattered occurrence in bogs and along lake margins where it is of little or no value, inaccessible, and easily overlooked. The aecial stage of the fungus closely resembles another indigenous and much more widely distributed rust, *C. filamentosum* which completely overlaps its range. These two factors contributed largely to the fact that the disease was not discovered earlier in the West.

In the fall, a wide distribution of the disease has been noted on *M. gale*, irrspective of the proximity of the aecial hosts. This distribution is attributed to long-distance dissemination of the rust by wind-borne aeciospores.

Both the aecial and the uredinial hosts occur transcontinentally between the northern limits of the known ranges of rust in the East and the West.

It is probable, therefore, that the disease also is transcontinental and that the eastern and western ranges of it are connected.

The disease is destructive to young *Pinus contorta* in the near vicinity of sweet gale. As high as 10 or more per cent of the seedlings may be killed in such situations. Studies indicate that nodes and internodes originating in the first four years of the life of the seedling only are sufficiently susceptible for the establishment of infection. Many of the trees have the faculty of largely recovering from the disease. Possible modes of infection and evidence on the development of resistance of the host are discussed.

No associations of the alternate host with *Pinus ponderosa*, which has shown itself to be highly susceptible in eastern nurseries, have been found. Such associations probably are rare, if they exist at all. Consequently, the rust can not be considered a serious threat within the native range of this pine.

Observations on *Myrica californica* at Ilwaco corroborated results of inoculation by others in the East, showing this species of Myrica to be immune. The fact that it ranges southward into the Oregon and California pitch- and hard-pine regions may be concluded to be of no significance in connection with the possible distribution of the rust into these regions.

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ECOLOGICAL STUDIES OF CURLY TOP OF SUGAR BEETS

WALTER CARTER[1]

ONE FIGURE

Studies on the ecology of *Eutettix tenellus* (Baker), during 1926, included a consideration of the environmental data from beet fields and covered the factors of evaporation, temperature, and light. Inasmuch as that year was a serious one for the sugar-beet industry in southern Idaho, an excellent opportunity was presented for study of these factors in the development of curly top.

Concurrent with these studies, an attempt was made to modify, by artificial means, factors of temperature, light, and moisture loss from the leaves under field conditions.

STATEMENT OF THE PROBLEMS

1. The development of curly top under artificial shade in the field and various light sources in the laboratory.

2. The effect of artificial control of environment on the development of curly top.

METHODS

Problem 1. Cages were constructed of three materials—(*1*) automobile celluloid, with the ends of the cages of a fine cloth mesh for ventilation; (*2*) "Celoglas" (a glass substitute), with ventilation provided by means of strips of cloth sewn into both ends and top; and (*3*) unbleached muslin. Two laboratory light boxes were made, one lighted by a quartz mercury-arc lamp (Uviarc Poultry Treater) under which a thin Pyrex-glass bowl was placed, and the other lighted by a 1000-watt clear Mazda lamp. Under this type of lamp, it was necessary to have a glass-bottom chamber through which water was constantly running in order to reduce the temperature.

Problem 2. Hydrated lime, zinc oxide, and lamp black were sprayed on the leaves of the beets. Difficulty was experienced in getting heavy suspensions through the sprayer, but by modifying the nozzles it was possible to use the formulae given below:

Lime—hydrated	50 lbs.
Calcium caseinate	3 lbs.
Water	30 gal.

Zinc oxide	40 lbs.
Calcium caseinate	3 lbs.
Water	30 gal.

Lamp black	8 lbs.
Calcium caseinate	3 lbs.
Water	30 gal.

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Measurement of factors. Light intensity was measured by comparison with a Kimball Sunshine Recorder (3). This measures total intensity and is not selective for the various wave lengths. For the laboratory chambers, the recorder was placed under the lights at the same distance from the lights as were the plants. For the outdoor cages, the record was taken by placing each cage consecutively over the recorder and noting the changed deflection of the needle. These data are listed in table 1. Air temperature was measured by means of "distance recording" thermographs. Humidity, or rather the evaporating power of the air, was measured by means of Livingston porous-cylinder atmometers.

THE DEVELOPMENT OF CURLY TOP UNDER ARTIFICIAL SHADE IN THE FIELD AND VARIOUS LIGHT SOURCES IN THE LABORATORY

Experiments were conducted with the three types of cages mentioned; the ultra-violet and 1000-watt clear Mazada lamps were also used in two of the experiments. The sunshine recorder was not available at this time, but later readings, as given in table 1, show that light intensity was greatest under celluloid, less under Celoglas, and least under cloth. In all these experiments the same number of leaf hoppers, taken from a very badly diseased field, was used, but these were not individually tested for virus bearing. The plants, which were of the same age and from the same lot of seed, were continually exposed to the insects during the whole period of each experiment.

The results of these experiments indicate that a greater percentage of plants developed the disease under celluloid and Celoglas than under cloth or the two types of artificial light. Differences in the severity of the disease were also marked. Under celluloid and Celoglas, pronounced curling and vein swelling were general, while under the cloth cage the symptoms did not, as a rule, develop beyond the clearing of the veins. None of the cases developing under the artificial lights ever progressed beyond that stage.

In another experiment, 15 plants were severely etiolated by growing them in a dark basement at 85° F. for six days. Outdoors 15 other plants were placed in a celluloid cage for the same period. At the end of this period five leaf hoppers were placed on each of the 30 plants and left there. Three days later the etiolated plants were removed to another, similar celluloid cage.

The result of this experiment showed only three cases of curly top in the etiolated set as against the 15 plants in the set kept outdoors previous to infection. All the cases of the disease in both sets were of the pronouncedly curled and vein-thickened type. This experiment indicates that the condition to which the plant is exposed at the time of inoculation affects the

TABLE 1.—*The intensity of sun's rays in the open and under cages of different materials and the intensity of two artificial lights measured by means of the Kimball Sunshine Recorder*

Sunlight				Artificial light	
In the open	Under Celoglas	Under celluloid	Under unbleached muslin	From 1000-watt Madza lamp	From ultra-violet lamp[a]
100	70	100	50	15	2
70	49	70	—	—	—
100	70	100	—	—	—
52	30	52	16	—	—
49	—	44	—	—	—

[a] Uviarc Poultry Treater with Pyrex screen.

number of positive cases even if conditions later are favorable to the development of the disease, but these results were not checked by further experiments. It might well be that conditions affecting susceptibility to infection are not identical with those affecting the development of the disease.

Additional experiments were conducted in the three types of outdoor cage in which the factors of light, temperature, and evaporation were measured in the manner previously described. The environmental data for these experiments are listed below in tables 2, 3, and 4.

In one experiment (see table 2), five leaf hoppers were caged on each plant and 10 plants used for each of the following conditions: the three outdoor cages, the ultra-violet and 1000-watt lamps, and also a temperature box kept at 85° F. No light was available in this last case.

Not a single case of disease developed in either the dark temperature box or under the ultra-violet light. Three cases of curly top developed under the 1000-watt lamp, of which one was of the curled and swollen-vein type. In case of the three outdoor cages, all the plants under celluloid developed disease of the pronounced type; in addition, the plants were badly stunted. All the plants under Celoglas developed disease of the same type, but stunting was not so pronounced. Under the cloth cage only three developed symptoms of the severe type though there were nine cases in all.

It should be noted that in this experiment the development of the disease varied directly with the amount of the three factors, light intensity, evaporation, and temperature, disease being most pronounced where these three factors were at a maximum. The light intensity was extremely low under the ultra-violet light, and was altogether lacking in the temperature

TABLE 2.—*The effect of light, evaporating power of the air, and temperature on the development of curly-top symptoms in sugar beets. Experiments made at Twin Falls, Idaho, July 8 to August 4, 1926*

Data recorded \ Outdoor cages and artificial lights		Celluloid	Celoglas	Cloth	1000-watt Mazda lamp	Ultra-violet lamp	Temperature box at 85° F.
Mean daily evaporation in cc.		36.4	34.8	30.00	——	——	——
Mean temperature in degrees F.	Maximum	110.0	109.0	98.0	——	——	85° F.
	Minimum	55.00	56.0	56.00	——	——	85° F.
Light intensity in gr. cal. per sq. cm.	Total	15,298.70	10,070.90	7,649.35	5,832.93	548.0	——
	Mean daily	611.5	428.3	305.7	216.04	20.3	——
No. plants with curly-top symptoms		10	10	9	3	None	None
Type of disease		All severe and plants stunted	All severe, but very little stunting	3 severe cases; 6 mild; no stunting	1 severe case; 2 mild; no stunting		

TABLE 3.—*The effect of light, evaporating power of the air, and temperature on the development of curly-top symptoms in sugar beets. Experiments made at Twin Falls, Idaho, July 21 to August 16, 1926*

Data recorded \ Outdoor cages and artificial lights		Celluloid	Celoglas	Cloth
Mean daily evaporation in cc.		29.6	27.2	27.0
Mean temperature in degrees F.	Maximum	111.0	108.0	106.0
	Minimum	56.0	54.0	52.0
Light intensity in gr. cal. per sq. cm.	Total	16,338.90	11,237.30	8,169.46
	Mean Daily	605.1	439.4	302.5
No. plants with curly-top symptoms		4	4	3
Type of disease		3 severe cases; 1 mild case; stunting very pronounced.	2 severe cases; 2 mild; vein thickening most pronounced. Some stunting.	All mild; no stunting or vein thickening.

box. This same factor was low, compared with the outdoor cages, under the 1000-watt lamp.

In another experiment (see table 3) which was limited to field cages, five *E. tenellus* were placed on each plant. Ten plants were placed under each of the celluloid and Celoglas cages and eight plants under the cloth cage. Growth was most vigorous under cloth, less in Celoglas, and least vigorous in the celluloid cage. Stunting was most pronounced in the celluloid cage, but the curling and vein thickening of the leaves was most conspicuous in the Celoglas cage. The three cases of disease which developed in the cloth cage were all of the faintest type.

TABLE 4.—*The effect of light, evaporating power of the air, and temperature on the development of curly-top symptoms in sugar beets. Experiments made at Twin Falls, Idaho, August 25 to September 13, 1926*

Data recorded \ Outdoor cages and artificial lights		Celluloid	Celoglas	Cloth
Mean daily evaporation in cc.		26.0	23.8	24.0
Mean temperature in degrees F.	Maximum	103.0	105.0	92.0
	Minimum	48.0	48.0	44
Light intensity in gr. cal. per sq. cm.	Total	13,110.0	9,175.0	6,555.0
	Mean Daily	524.4	367.0	262.2
No. plants with curly-top symptoms		9	8	8
Type of disease		7 severe cases; 2 mild; stunting pronounced	7 severe cases; 1 mild case; very little stunting.	6 severe cases; 2 mild; yellowing and stunting very pronounced.

In the third experiment (see table 4) no difference could be observed in the type of disease which developed. This was the last experiment of the season and the evening temperatures were low. The sun's intensity was much diminished, so that the total intensity under the cloth cage was brought down to the point where it probably was too low for normal growth. The plants in this cage were yellowed as well as stunted.

THE EFFECT OF ARTIFICIAL CONTROL OF ENVIRONMENT ON THE DEVELOPMENT OF CURLY TOP

Makers of paints and varnishes have devoted considerable attention to the effects of environment in producing "weathering," and it was after

reading a paper by Harley A. Nelson (4) that the writer conceived the idea that possibly an application of some light-screening pigment to the leaves of the sugar beet would have some effect on the development of the disease and the consequent weight of the beet at harvest time.

G. F. A. Stutz (6) describes the absorption coefficients of various paint pigments. Table 5 gives these data, and it was on the basis of these that the materials for this experiment were chosen.

There are no data available for the hydrated lime which was used, but so far as is known this material has no capacity to screen out the shorter wave lengths of the light spectrum.

TABLE 5.—*The absorption coefficients of two paint pigments. Taken from the work of Stutz (5, p. 92–93)*

Pigment	Coefficient of diffuse reflection at wave lengths							
	5461	4358	4047	3655	3131	3024	2968	2536
Zinc oxide	97	87	80	3	0	0	0	0
Lamp black	5	4.5	3.8	4.2	4.2	4.3	4.5	4.4

Builders' ordinary slaked lime and hydrated lime were also used. The former had to be abandoned owing to the impossibility of getting a mass finely enough divided. The hydrated lime worked through the sprayer very well, but with the weight of material used, frequent cleanings of the machine were necessary. The experimental plots of The Amalgamated Sugar Company at Twin Falls, Idaho, were used for this experiment. Two places were chosen, each with a different planting and thinning date. In the case of one plot, the spray was applied before thinning. The data for this experiment are shown in table 6.

Differences in dates for these sprayings were due to practical considerations. Each type of spray was applied as near the same date as possible. Plot 2 was planted after the migration of leaf hoppers into the fields had occurred, but the numbers of *E. tenellus* in this plot indicated that there had been a decided movement from surrounding plots.

The experiments during 1926 were conducted under as severe curly-top conditions as could be imagined. In order to compare the results with those obtained when curly top was not a factor, experiments were conducted on small plots during 1927. In the Twin Falls area in 1927, beets made remarkable growth and were only slightly affected by curly top, so the results for that season can be taken as representing the effect of the pigment sprays under normal conditions. Spray was applied on June 24, July 2, July 20, and August 5. The harvest data are shown in table 7.

TABLE 6.—*The effect on yield of applications of light-screening pigments to sugar-beet leaves*

Plot 1. (*Planted April 8, thinned May 10, 1926*)

Spray material	Dates of spraying	No. plants in row at beginning of exp.	No. beets harvested	Beets which weighed 1 lb. or more		Beets weighing 8–15 oz.	Total weight of beets (lbs.)
				No.	Weight (lbs.)		
Zinc oxide	June 1, 10, 19 and July 6	145	125	17	.....	15	48.0
Check		143	129	24	.....	22	53.9
Lamp black	June 5, 9, 24, 30 and July 15	155	114	7	.....	18	30.6
Check		141	132	24	.....	19	63.4
Lime (hyd.)	June 5, 8, 23 and July 8	142	134	33	.....	19	82.0
Check		154	147	18	.....	26	64.7

Plot 2. (*Planted May 17, thinned June 25, 1926*)

Spray material	Dates of spraying	Size of plot	Beets which weighed 1 lb. or more		Beets weighing under 1 lb.		Total weight of beets (lbs.)
			No.	Wt. (lbs.)	No.	Wt. (lbs.)	
Lime	June 11, 26 and July 6, 17	6 rows 300 feet long	144	207.5	1163	473.5	681.0
Check		do	66	107.0	1091	376.5	483.5
Lamp black	June 13, 27 and July 10	do	28	42.0	965	294.0	336.0
Check		do	26	40.5	774	307.0	416.0
Zinc oxide	June 17, 28 and July 9	do	38	57.25	843	310.0	367.25

TABLE 7.—*The effect on yield of applications of light-screening pigments to sugar-beet leaves. Data taken from experimental plots in 1927*[a]

Pigment	Total yield of beets (lbs.)	Pigment	Total yield of beets (lbs.)
Zinc oxide	620	Check	695
Hydrated lime	690	Check	700
Lamp black	340	Check	610

[a] Each plot consisted of two rows of beets 180 feet long.

During the summer, occasional records were taken of the surface temperature of normal and of treated leaves. This was done by means of a thermocouple which was held close to the surface of the leaf, the operator avoiding interference with the sun's rays and keeping at arm's length from the plant. These readings revealed the fact that the surface temperature of all the leaves tested, sprayed and unsprayed, were similar to within a degree Centigrade, even though the leaves of the treated plants presented two entirely different absorbing surfaces, white of the zinc oxide and lime and black of the lampblack.

In a recent paper, Angstrom (1) gives data on the solar intensity transmitted through leaves of various species. He obtained these data by carefully fastening the leaves over the glass globe of a sunshine recorder of the thermoelectric type and recording the light transmitted. Using the same method, beet leaves were fastened over the globe of a Kimball pyrheliometer (fig. 1) which was then placed under a 100-watt Mazda lamp. After the record of transmission through the normal leaf was obtained, the leaves

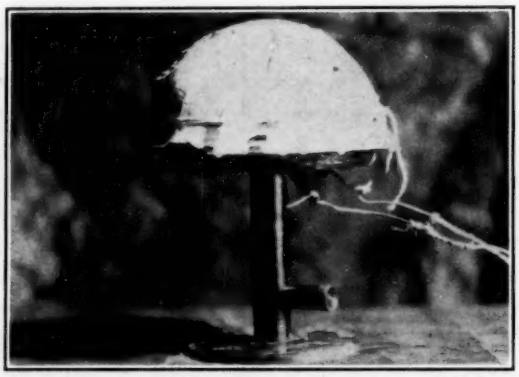

FIG. 1.—Kimball pyrheliometer, showing method of obtaining transmission through beet leaves. The glass globe is covered with beet leaves carefully fastened together and, in the case figured, coated with lime spray.

were sprayed with lampblack of the same density as that used in the experiments. The record was again obtained. This was done for each of the three pigments, using a new set of normal leaves in each case. These data are presented in table 8.

TABLE 8.—*Data on transmission of light through sprayed and unsprayed beet leaves*

Light transmission of unsprayed leaves		Light transmission of sprayed leaves		Reduction in light transmission by foliage spraying (per cent)
Unsprayed No. 1	31[a]	Lampblacked	10	68
Unsprayed No. 2	38	Zinc-oxided	23	40
Unsprayed No. 3	34	Lime	22	36

[a] Reading direct from chart for purposes of comparison only.

The three pigments used vary considerably in their capacity as light screens. Both lampblack and zinc oxide are efficient in screening out the shorter wave lengths of the spectrum. Both zinc oxide and lime, being white, reflect the longer wave lengths, whereas lampblack absorbs them. Lime has little capacity as a screen against the short wave lengths.

The severe reduction in yield of plants sprayed with lampblack was common to both seasons, 1926 under severe curly top conditions and 1927, when curly top was not a factor. It is evident, then, that the pigment seriously affected the normal functions of the plant. This interference was probably with the three factors of temperature, moisture loss, and light. Clum (2) concludes that leaf temperatures depend upon a balance between light intensity and convection and radiation, but considers transpiration insignificant as a factor in reducing temperature, at least in Ithaca, N. Y. The fact that the plants sprayed with lampblack wilted down when all other plants in the experiments were not so affected, supports the view that moisture loss was very greatly increased through the absorption of heat by the black surface; the reduction of the temperature of the leaf surface to that of normal beets is evidence of the plant's response.

The data from the plots which were sprayed with zinc oxide indicate a slight reduction in yield in both seasons. Since the plant was protected from extreme heat by its white heat-reflecting cover, this reduction could not have been due to abnormal moisture loss. Photosynthesis was probably seriously interfered with; however, the possible toxic effects of the zinc oxide have not been investigated. In the case of the other two pigments used, toxicity of the material is unlikely, in view of the fact that one consists of finely divided carbon and the other of an inert carbonate.

The results from the plots sprayed with hydrated lime are most interesting, since in the case of this material there is a significant difference between the yields of the two seasons. In 1926, when curly top was a serious factor, the plot sprayed with hydrated lime was superior in yield to its check. In 1927 there was no significant difference between it and its checks, and in that season curly top was barely present in the plots. This result suggests that the development of curly top was conditioned by the presence of the lime screen on the leaves. As has been mentioned, lime is a very inefficient screen for the shorter wave lengths of the spectrum but provides a white reflecting surface. There was, then, very little interference with photosynthesis and at the same time moisture loss was reduced, owing to the reflection of heat from the leaf's surface. Since it has been shown in the first section of this paper that extreme conditions of temperature, evaporation, and solar intensity favor the development of the disease, the explanation that the effect of the hydrated lime spray was through reduction of the intensity of these factors is at least plausible.

The relative importance of the three factors mentioned is difficult to determine, especially as extremes of one are usually associated with similar extremes in the others. Certain field data are available through the courtesy of the Amalgamated Sugar Company. These data are presented in table 9, and are concerned with the course of the disease and its severity in a beet-growing area which includes considerable subirrigated land.

TABLE 9.—*The effect of different types of irrigation on the yields from sugar-beet fields in which curly top was present*

Yield	Subirrigated fields	Surface-irrigated fields
Not harvested	47.50%	86.98%
5–9 tons	36.66%	12.06%
Over 9 tons	15.75%	0.95%

These data illustrate the fact, well known to workers on curly top, that land kept moist and therefore cool, permits beets to withstand more easily the development of the disease. Presumably the evaporating power of the air just above the subirrigated beets was considerably less than over beets irrigated in the ordinary way; but, even if this was not the case, subirrigated beets do not suffer from drought in the early stages and this fact no doubt contributed to the vigor of these beets. It has been the common experience in this subirrigated area that even in the years of worst curly-top infestation, many fair and some good yields have been obtained. No subirrigated land exists near the Twin Falls factory, but it is perhaps significant that the only field producing 10 tons to the acre in 1926 was underlaid

by a leaky pipe line. The position of this pipe line could easily be traced across the field, since the beets over it were of large size and in healthy condition.

Field observations on the effect of low light intensity in retarding the development of the disease are numerous, but since this factor is invariably associated with low intensities of the factors of temperature and moisture loss it has not been possible to evaluate its individual importance. Shapovalov (5) came essentially to the same conclusions as to the importance of these factors in his studies on western yellow blight of tomatoes, a virus disease of the same origin as curly top.

SUMMARY AND CONCLUSIONS

The development of curly top appears to be more severe under conditions of high light intensity, temperature, and evaporation than under conditions where these factors are reduced in intensity. The number of positive cases appears to be greater under conditions of high light intensity, temperature, and evaporation. One experiment indicates that the conditions governing susceptibility to infection are not the same as those conditioning the later development of the disease. Experiments on the control of the external environment indicate that lampblack and zinc oxide, when sprayed onto the leaves, interfered with the normal functions of the plant and did not favor the development of the disease. Hydrated lime reduced the severity of the disease but did not affect the normal beet.

The kindness of Drs. Burton E. Livingston and H. H. Kimball in answering questions concerning their particular fields is gratefully acknowledged. Dr. Eubanks Carsner, of the Bureau of Plant Industry, has reviewed the manuscript and made valuable suggestions in connection therewith. Messrs. C. H. Griffith and V. E. Romney assisted with the field work during the entire experiment.

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NEMATOSPORA ON POMEGRANATES, CITRUS, AND COTTON IN CALIFORNIA[1]

HOWARD S. FAWCETT

The purpose of this paper is to give a brief report of observations and experiments with respect to a Nematospora found on pomegranates and citrus in Imperial County, California, in September, 1928, and, later, found widely distributed in the same county on cotton bolls.[2] This fungus probably is *Nematospora Coryli* Peglion. The Western leaf-footed plant bug, *Leptoglossus zonatus* Dallas was found to be carrying the fungus from the pomegranate to citrus. This appears to be the first recorded occurrence of this fungus on the three above-named hosts in the United States. The pomegranate appears to be a new host for the fungus and this plant bug is a newly reported carrier of the fungus. Accepting Ashby and Nowell's (1) conclusions that *Nematospora Coryli* also includes *N. phaseoli* Wingard (2) and *N. lycopersica* Schneider (3), the only other reports of its occurrence in the United States appear to be that on beans in Virginia and that on tomatoes in southern California.[3] It has been reported by Nowell (1, 4) on citrus, cotton, and fifteen other hosts in the Lesser Antilles. It was reported by Lee (5, 6) on citrus in the Philippine Islands, Japan, and China, and recently by Rhind (10) on cotton in Burma, India.

Another quite distinct species, *N. gossypii*, has been described recently by Ashby and Nowell (1) as having been found on cotton and on two other hosts in the Lesser Antilles. The last species also has been found on cotton in Nigeria, Africa (7).

In general, *N. Coryli* causes a staining and collapse of the tissue, resulting ultimately in desiccation and frequently in a dry rot. In pomegranates there first appear depressed, light-colored spots in the fleshy covering surrounding the seeds. These later develop into a general browning and collapsing of certain regions of the pulp involving the fleshy part of many adjacent seeds. In citrus there is a collapsing and drying out of the juice sacs just inside the rind. The effect noted on oranges, grapefruit, and tan-

[1] Paper No. 203, University of California Graduate School of Tropical Agriculture and Citrus Experiment Station, Riverside, California.

[2] Plant Disease Reporter, Bureau of Plant Industry, U. S. D. A. 12: No. 14, pp. 145–146. December 1, 1928.

[3] Schneider, in Phytopathology 6: 395, says that the first tomatoes examined were obtained from a restaurant in Berkeley, California, whose proprietor maintained that they were from the South Sea Islands, but the author thought it more likely "that they came from Mexico or perhaps from Cuba." In Phytopathology 7: 52, it is stated under *Habitat:* "Parasitic on nearly ripe and ripe fruit of *Lycopersicum esculentem*, southern California, Cuba and Mexico."

gerines in the Imperial Valley, California, was a brownish to reddish brown stain in a portion of each of the juice sacs attacked. In time this results in a drying out and deterioration of a considerable portion of the pulp without any spotting or deterioration on the exterior of the rind (Fig. 1).

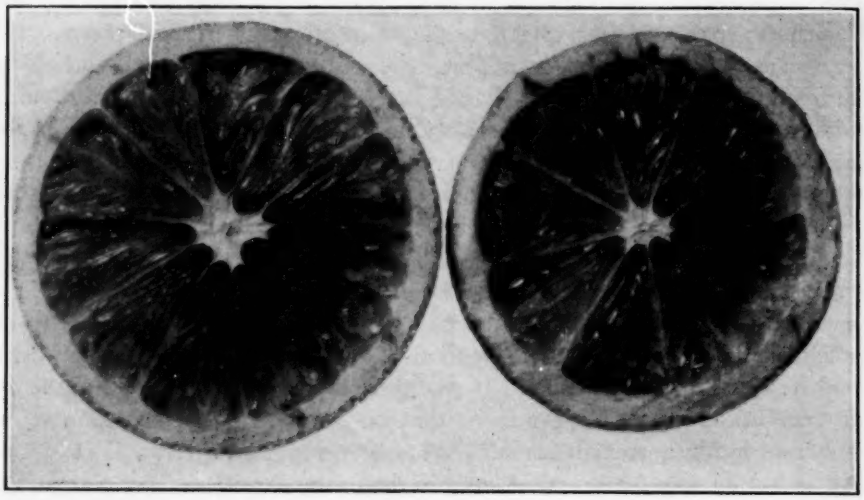

FIG. 1.—Oranges showing breaking down and drying of juice sacs due to *Nematospora Coryli* introduced through punctures of *Leptoglossus zonatus*.

If immature fruit is punctured by the bugs carrying this fungus, it begins to color prematurely and tends to drop from the trees. In the Philippine Islands, Lee (5) found, in addition to the drying out, a marked thickening of the divisions. In young cotton bolls the seeds are discolored and the inside portions become brown and dry. The immature lint was at first yellowish and later dark reddish-brown and dry, this discoloration and drying spreading various distances from the original punctures.

Experiments showed that the disease could be transmitted readily by placing leaf-footed puncture bugs, *Leptoglossus zonatus*, found on infected pomegranates, onto sound oranges and lemons in jars in the laboratory. In two or three weeks the symptoms developed on the inside of the fruit. One of the first indications of the presence of the disease in green fruits was a much more rapid yellowing on those which had been punctured by the bugs than on fruit not punctured. A fungus was isolated readily on glucose-potato agar and on corn-meal agar by transferring juice sacs with sterile instruments to the surface of slants. The growth of the California strain obtained from citrus on glucose-potato agar first resembled that of yeast. With age the growth tended to form an irregular and somewhat wrinkled surface resembling that illustrated by Ashby and Nowell (1). On corn-

meal agar the fungus grew much slower, with a considerable margin of mycelium-like growth on the surface of the medium.

Attempts were made to isolate this fungus from the beaks of several individuals of *Leptoglossus zonatus* but no Nematospora was obtained. *Aspergillus niger,* however, which also was being carried from pomegranates to citrus by these bugs, was readily isolated. Microscopic examinations of the beaks and other parts of the insect failed to reveal Nematospora, but showed many spores of Aspergillus adhering to the sides of the beaks. The small, yeast-like cells of Nematospora might be carried in small numbers without being easily identified under the microscope.

Experiments showed that the Nematospora, when transferred from pure culture by needle punctures into immature Navel oranges, would cause these fruits to turn yellow more quickly than those punctured with a sterile needle. Lee (5) already had shown that the Philippine fungus would infect citrus fruits when transferred to it by needle punctures. The California strain was found to grow very well on the glucose-potato agar at temperatures from 15 to 32° C. The growth was very slight even in 30 days at a temperature of 8.5° C. During a 10-day period its growth was greatest at 25.5 and 27.5° C. At all temperatures tried between 15 and 32° C. there occurred an abundance of asci and spores. Although different temperatures produced no striking differences in the general macroscopic appearance of the growth, they had a decided influence on the length of the asci. The following measurements were typical of the length of the asci found at different constant temperatures:

21.5° C., 72– 80 μ
24° C., 80– 93 μ
25.5° C., 88–102 μ
27.5° C., 104–106 μ

The width, varying between about 8 to 12 μ, did not appear to be related to temperature. The spores were apparently the same length (approximately 40 x 2.5 μ) irrespective of the length of the asci.

It is suspected that the fungus has been present in southwestern United States and Mexico for a long time, as indicated by descriptions of injury to cotton bolls in previous entomological literature. Morrill (8), in 1910, described an injury to cotton bolls in Mexico and Arizona, strikingly similar to the Nematospora injury which the author has recently observed where Nematospora is abundant. McGregor (9), in 1927, referring to some work done from 1916 to 1918, in the Imperial Valley, makes the following statement regarding the tarnished bug, *Lygus elisus* Van Duzee: "Since the actual mechanical injury associated with the feeding of Lygus is slight, compared with the resulting damage, it seems reasonable to suspect that

either a toxic material or an organism may be introduced into the plant tissue at the time of feeding."

The descriptions and illustrations by these two authors of the more severe phases of the damage strongly indicate that Nematospora or other similar fungus has been for a long time a factor in the injury. This suspicion is strengthened by the report of recent experiments by Laycock and Jones (7) with the cotton stainer in connection with *Nematospora gossypii* in Nigeria, where very slight damage was produced by the punctures of bugs bred under sterilized conditions as compared with punctures from those known to carry the fungus.

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A PROGRESS REPORT ON THE CONTROL OF CROWN GALL, HAIRY ROOT, AND OTHER MALFORMATIONS AT THE UNIONS OF GRAFTED APPLE TREES[1]

A. J. Riker, G. W. Keitt, and W. M. Banfield

An effort has been made to find a satisfactory control of the various malformations which occur in the nurseries at the unions of apple trees grown from piece-root grafts. Following the work of Smith, Brown, and Townsend (10), all these malformations, except those caused by insects, have been classified by most workers either as crown gall or hairy root, and attributed to the crown-gall organism, *Bact. tumefaciens* Smith and Town. More recently a series of papers by Brown (1), Muncie (5), Riker, Banfield, Wright, and Keitt (7), and Riker and Keitt (9) have presented evidence that the problem is concerned not only with infections by a single species of bacteria, but rather with those of at least two species of bacteria and with certain non-parasitic troubles. In view of the complexity of the problem, it is not surprising that adequate control measures have developed slowly.

The control measures thus far tried fall into three major groups: (a) use of antiseptics applied to the soil, to the wrappers employed, or to the finished graft (Hedgcock, 2; Melhus and Maney, 3; Oppenheimer, 6; Sherbakoff, 11; Waite and Siegler, 12; and Wormald and Grubb, 13); (b) modifications[2] of the grafting methods (Hedgcock, 2; Melhus, Muncie, and Fisk, 4; and Riker and Keitt, 9); and (c) modifications in wrapping materials and methods (Hedgcock, 2; Riker, Banfield, and Keitt, 8; and Riker and Keitt, 9). The problem of control has been approached by the writers in all these directions in a long series of experiments during the past five years. While various methods have given promise in certain individual experiments, only one of them in the writers' trials has been found to give consistently favorable results over a considerable range of conditions (Riker, Banfield, and Keitt, 8; Riker and Keitt, 9). This method centers about the use of adhesive plaster as a wrapper for well fitted grafts.

[1] Published with the approval of the Director of the Wisconsin Agricultural Experiment Station. These studies were begun as a part of the Wisconsin program in the crown-gall project supported cooperatively by the Crop Protection Institute, the Iowa State College of Agriculture and Mechanic Arts, and the University of Wisconsin, and have been continued in cooperation with the United States Department of Agriculture.

[2] While it is outside the scope of this paper, mention should be made at this point of the practice of budding which avoids the kind of union provided by the piece-root graft. The root-knot difficulty has been virtually obviated in many eastern nurseries through this practice. However, for various reasons, most of the nurserymen in the middle west still prefer to propagate their apple trees from piece-root grafts.

The use of adhesive plaster, or nurserymen's tape, has been sufficiently successful in experimental plots to deserve extensive trials by the propagators of apple trees from piece-root grafts. Experiments have been conducted with this wrapper[3] on apple during four years under a variety of conditions covering a geographic range which included Iowa, Kansas, Minnesota, Missouri, Nebraska, Oklahoma, and Wisconsin. The usual practice of employing grafts with a five- or six-inch cion and a three- or four-inch root has been followed. When the plaster was correctly applied to grafts of this size, no trials have yet been made in which it failed to rot before there was danger of girdling. The methods of employing plaster in special cases where a very short cion (two inches long) is used or in regions where irrigation is employed have not been worked out. Under such conditions, it is possible that the plaster might remain too dry and fail to rot soon enough to avoid girdling. While the plaster doubtless has promise of value on a much wider range of plants, results are available only on apple. In the trials made thus far, the plaster, on the average, has shown no influence on the stand of trees when compared with the commercial string wrapper. Considerable fluctuation in stand, both against and in favor of the plaster, has been observed in the same localities in successive years and in different localities in the same year. However, the plaster has shown a distinct influence on the prevention of root-knots at the union. In no single experiment in any year has it failed materially to increase the percentage of trees with smooth unions. The effectiveness of the plaster has varied with the amount of disease present. While less complete control was secured in southern than in northern regions, in some years when root knot was very severe, the value of plaster in the south was emphasized when the percentage of smooth trees wrapped with plaster was compared with that of smooth trees wrapped with the commercial string. A digest of the field data for 1928 on the value of plaster compared with string for the prevention of root-knots has been prepared. This is summarized in table I.

The cost of applying the plaster is comparatively small, and varies with the methods employed. In some nurseries the use of plaster does not increase the cost. On the average, one good tree saved out of a hundred more than pays for the increased cost. No nursery has been found where, when the plaster is correctly applied, the increased cost is not covered by a saving of two good trees out of a hundred.

The method of applying the plaster is quite simple. The grafts were well made in the usual manner from clean cions and roots free from disease.

[3] The nurserymen's tape employed in these tests was supplied by Johnson and Johnson, New Brunswick, N. J. It is a modification of their zinc oxide medical adhesive plaster, the chief differences being the omission of zinc oxide and the use of a cheaper fabric.

TABLE I.—*Summary of experiments in 1928 which compare cotton string and adhesive plaster wrappers in relation to the occurrence of malformations at the union of piece-root apple grafts*

Number and location of trials	Age of trees	Graft	Wrapper	Smooth	Small knots[a]	Large knots[b]
	Years			per cent	per cent	per cent
Average of six trials in Iowa, Kansas, Minnesota, and Oklahoma	1	Wedge	String[c]	59	20	21
	1	do	Plaster	91	4	5
Average of eight trials in Iowa, Kansas, Minnesota, and Oklahoma	1	Tongue	String[d]	56	17	27
	1	do	Plaster	95	3	2
Average of four trials in Minnesota, Nebraska, and Wisconsin	3	Tongue	String[d]	71	5	24
	3	do	Plaster	91	2	7

[a] This class included all enlargements, regardless of cause, smaller in cross measurements than half the diameter of the tree.

[b] This class included all enlargements larger across than half the diameter of the tree.

[c] The stand was reduced in some cases in which the wedge grafts were wrapped with string and subsequently broken in handling. No breaking occurred when the grafts were wrapped with plaster.

[d] The stands of trees wrapped with string and plaster wrappers were approximately the same.

The method was equally successful with either tongue or wedge grafts. A half-inch-wide roll of nurserymen's tape was mounted on a roller at the side of the operator. The tape was applied in a spiral wrap over every part of the union. Care was taken to overlap the edge of the plaster slightly and to make a water-tight covering over every part of the cut surface. The tape was cut to the desired length for the graft in hand just before the final inch was applied. It was cut on a section of a cutter-bar or some other knife conveniently mounted in front of the operator. The tape was applied so that no more than two thicknesses of material circled the graft at any one point. After a little practice 350 to 400 grafts were wrapped in an hour. The grafts were stored and planted in the usual manner.

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PLANT QUARANTINES AND THE STATE

W. A. McCubbin

In looking over the organizations which have been developed in the various States to carry on quarantine and inspection activities, one is struck by the great diversity in the agencies assigned to this duty. It is true that 45 out of 48 States center their legal quarantine power in either a department of agriculture or a State board of agriculture. But these administrative bodies carry out their functions through a great variety of agencies or individual officials. In 4 States, a plant board controls these activities; 23 others concentrate the work in an administrative subdivision, usually a bureau or division devoted to plant industry, inspection, orchards and nurseries, entomology, pest suppression, farms and markets, horticulture and the like. Thirty-two States entrust the quarantine function to an individual who is usually the State entomologist though he may be a chief inspector, supervisor of horticulture, agricultural inspector, State horticulturist, seed analyst, or a general State agricultural officer. In 20 out of 48 cases such official is at the same time on the extension service or experiment station staff. Is this wide diversity in administrative machinery a source of weakness in quarantine enforcement? Does the method of State organization affect the efficiency of quarantine work to such an extent that something should be done about it? Probably not. The administrative function has been demonstrated over and over again to possess such great flexibility that it can exert its full powers through any of the diverse channels mentioned, and one may therefore conclude that almost any type of administrative agency is acceptable, so long as it meets certain basic requirements.

Among these requirements, a well grounded legal authority should undoubtedly be given first place, and this requirement would be closely followed by its complement of adequate funds and staff. Next, the quarantine agency must contain within its own organization or be able to command from elsewhere that technical knowledge which is nowadays in constant demand, not only in forming policies, planning operations, and meeting crises, but in meeting every requirement of ordinary procedure. Again, the quarantine office must be prepared to deal with those phases of its problems which extend into the field of survey, research, service, and public education. Further, provision should be made for close and sensitive contact with all the interests in the State affected in various ways by quarantine activities; and finally the State agency must be equipped in these complex times to maintain itself on a basis of mutual understanding and cooperation

with other States and with the Federal authorities. Granted that these six basic requirements are met, there seems to be no reason why any existing type of State organization should not carry out quarantine functions competently and successfully.

It is not the purpose of this discussion to inquire to what extent individual States fulfill these requirements; but we may properly comment on the relation of these requirements to the general quarantine situation.

The first requirement touching the need for legal power may be passed with the remark that during the last few years there has been widespread tinkering with and remodelling of various State statutes, with the result that many former legal handicaps are rapidly disappearing.

The supply of man and money power is improving somewhat but there is general agreement that it is still far from satisfactory. Not a few of the disappointments and shortcomings in quarantine and inspection work have their origin in the combination of an earnest, conscientious official and a too slender appropriation. All too frequently a sense of public duty urges the planning of a logical program which then cannot be completed for lack of funds.

In this connection there should be mentioned also the numerous cases where precious weeks or months have been lost before the energies of the State could be released by legislative enactment into the field of control. The recent establishment in many States of emergency funds designed to meet sudden outbreaks of insects or diseases indicates that this logical procedure will shortly become a universal policy.

Passing over the need for the best technical knowledge available as a point too obvious to require comment, we come to review the relation of the State quarantine office to certain other closely related activities. Perhaps out of the four mentioned—survey, research, service, and public education—the first is in the most unsatisfactory state. In spite of the lessons of the past, we still continue to impose quarantines without adequate knowledge of the distribution of the pests concerned; yet it is not so much that the quarantine is too hastily applied as that the survey trails too far in the rear. What we need is more and better—and one might add, quicker—surveys.

In the domain of public relations, the quarantine agency has a difficult part to play. It is, on the one hand, dependent on public support and, on the other, subject to public criticism. To develop and maintain the confidence of enlightened public opinion in the State, is important in the present conduct of its work and necessary for its continuity. It is suggested that where any type of regulatory work is established in a State it should be accompanied by a corresponding independent popular body repre-

senting the interests chiefly affected. Through such a body a real and correct understanding of the administrative aims and methods can be widely disseminated and, conversely, popular sentiment on the subject can be gathered and concentrated. A body or association of this kind can furnish support on the one hand and serve as a very efficient check on the other.

Up to this point, the functions of quarantine agencies have been considered only in relation to the State itself. When one comes to envisage regulatory matters from the interstate standpoint, there is at once apparent a somewhat perplexing situation. The perplexity arises partly from the independent and widely varying policies, standards, and procedures extant in the different States, and partly from conflicting opinions as to the respective rôles which should be assumed by the State and Federal authorities in the regulation of interstate affairs.

It is true that the now historic Supreme Court decision of 1925 has helped to clear the air somewhat. Previous to that period, the various States enacted and enforced such quarantines as they pleased almost regardless of Federal quarantines covering the same subject. The Supreme Court ruling held that since the U. S. Constitution vested control over interstate commerce in the Federal administration, the imposition of a quarantine under that authority should imply that due consideration had been given to the matter and that the action taken must be regarded as adequate both as to subject and area. Consequently, all conflicting State action was void. The decision went still further: It took the ground that absence of Federal action should be presumptive evidence that no action was required, and thus, in effect, denied to the States all authority over interstate shipments. If the principle here established were carried to its logical conclusion it would mean Federal control over all interstate shipments of materials concerned in the spread of insects or diseases. Such control must inevitably involve a multiplication of Federal quarantines, vast additions to the Federal staff and enormous increase in Federal expenses.

Fortunately, Congress soon cleared up the situation, providing by resolution an interpretative clause which stated in effect that, until the Federal authority had acted on a subject, individual States were free to take such measures as they deemed necessary. Even with the State power of quarantine thus partially restored there are those who view the outcome of this incident with alarm, seeing in it an encroachment on jealously guarded State's rights. This attitude is perhaps too extreme. With equal justice, the claim could be made that this court decision merely served to restrict the activities of the States within the bounds originally established by the constitution.

As matters now stand, no future conflict is likely to arise from a clash of State and Federal quarantines. But there still remains largely unsolved the original problem of how to obtain a much desired uniformity in quarantine action, inspection, and other regulatory functions among the States, particularly in the field not as yet covered by Federal action.

It is perfectly obvious that further extension into this field of Federal power, backed as it is by constitutional authority, would provide an effective means of unification among the States. But against unlimited extension of this kind are arrayed the economic arguments mentioned, as well as the defenders of State rights.

I am not aware that such extension is desired by any individual, group, or party; one could surmise that the Federal administration grew to its present proportions largely because of a continual thrusting upon it of added duties and responsibilities, rather than because of its grasping disposition. And it is probable that it would be forced into taking control of many matters in the field of interstate relations with great reluctance.

Perhaps the vital objection to placing on the Federal shoulders too great a burden of interstate quarantine and regulatory matters lies not so much in endangering State rights as in encouraging a definite trend away from local self-government. Our form of government depends on the intelligent interest of its citizenship in public affairs and their readiness to step in and help when difficulties arise. With the center of control and responsibility removed to Washington, the nation stands to lose in public knowledge and interest and sympathy and support much of what may be gained in standardization and efficiency. Such action tends to remove from the hands of the people the strings with which they have heretofore been accustomed to control their own destinies.

Still other objections may be raised against certain forms of Federal activity. The difficulties which arise when Federal quarantine action is directed against a small area in the State's interior are well known, and interstate nursery shipments provide an example of the awkward situation which would arise if the Federal power provided by the constitution were exerted in the field of inspection. It is difficult to see how a Federal certificate for interstate traffic could be issued without Federal inspection; yet such inspection would have no jurisdiction over stock grown and sold within the State, itself. Shall we then have two sets of inspectors for the same nursery? That way madness lies.

We are forced to conclude that while the exercise of Federal power to control the interstate spread of insects and diseases is constitutionally unlimited, yet there is a field in interstate relations in which it is subject to practical limitations. In certain problems Federal action will be

entirely beneficial, in others, the benefits will be counterbalanced by definite disadvantages, and in still others the obstacles are to all intents and purposes prohibitive.

It would seem then that we must look elsewhere for help in straightening out the tangles in certain aspects of interstate relations. To what source may we turn? At the present time the most hopeful outlook lies in agreements made between the states themselves. If these political units, recognizing the difficulties of the situation, can get together on matters of general policy, agree on inspection standards, provide for uniformity in procedure, and plan for concerted action in a common cause, the most pressing of their problems can soon be solved. And to facilitate just such action, we now have the Plant Board system.

The organization of the four regional boards composing the plant-board system was modelled largely on that of the Western Plant Quarantine Board, and it was the success of this body in the Pacific Coast States which suggested the formation of similar systems in three other regions. The States comprising each of these regions have many common problems arising out of geographic and climatic conditions and similarity of crops. The groupings thus formed outside the Western Board include the Eastern Plant Board covering the New England and Middle Atlantic States, the Southern Plant Board, composed of the States in the Cotton Belt, and the Central Plant Board embracing the great cereal district of the upper Mississippi basin.

In each State within a district, the officials in charge of quarantine and regulatory work appoint representatives on the regional board, usually for yearly periods. The assembled board elects its own officers, adopts its own constitution and by-laws, and, in short, conducts its affairs as an ordinary conference body. It is understood that the relationship of these boards to the States in their region is of a purely advisory nature and that no State administration is bound by decisions of the board or by commitment of members.

When the formation of these four boards was completed, every State in the Union was represented, and the next step was to provide a means whereby the work of the regional boards could be nationally correlated. For this purpose, each regional board was asked to appoint two representatives, the eight thus chosen to form the National Plant Board. This body was intended to function in a national way in much the same capacity as the regional boards in their groups of States.

What are the aims and functions of the Plant Board System? In the first place, the most urgent responsibility before these boards is an endeavor to bring about in each regional group and even on a country-wide basis, as

far as possible, uniformity among the States in the field of inspection. The nursery inspection service is in dire need of such reformation and is being given much attention. It is realized that the unification process must reach deeper than the mere form of certificates used and must cover such things as standards and even methods of inspection.

Second, the plant boards recognize the value of agreeing on a common policy in the establishment of interstate quarantines. It may be noted here that the National Plant Board is now attempting to draw up a set of principles of quarantine which it is hoped may serve as a guide in quarantine procedure.

Third, these bodies serve as a valuable clearing house for the exchange of ideas on general policies and practices in disease and insect control.

Fourth, the plant-board system provides, on the one hand, an orderly and organized channel through which the collective opinions, suggestions, and requests of the various States can be presented to the Federal authorities, and on the other hand, it represents a widespread influence which may be needed from time to time in the support of Federal undertakings.

From this brief outline of organization and purpose, it may be gathered that the plant board system, while no doubt conferring much benefit on each State because of the constant interchange of ideas on methods and policies, has as its great field of usefulness those matters which concern interstate as well as Federal-State relations. And since this field just now presents many perplexing problems, there exists a very excellent opportunity for this new type of organization to distinguish itself.

If the plant-board system can help in the solution of these interstate difficulties it may not only become a valuable and permanent acquisition from the State's point of view, but may be welcomed by the country at large as a hopeful means of settling many awkward features of Federal-State relations.

BUREAU OF PLANT INDUSTRY,
HARRISBURG, PENNSYLVANIA.

SOME PRESENT-DAY PROBLEMS[1]

H. P. Barss

In the past twenty years which have elapsed since the founding of the American Phytopathological Society there have been great developments in our knowledge of plant diseases and in our methods of dealing with them. The contributions to this progress which have been made by our members may well be a source of gratification to the founders of this Society. Throughout these two decades this organization has fostered a spirit of comradeship and exerted a stimulus to achievement the effects of which cannot be underestimated.

It would be interesting to look back over these years and survey the advances which have been made; but, in discharging the responsibilities of the office with which you have honored me, I would prefer rather to look forward and discuss with you some of the problems which challenge our attention as plant pathologists and members of this Society.

Phytopathology. Of most direct concern, undoubtedly, to every member of this Society is the problem of how to insure adequate present and future support for our journal, Phytopathology. Our Society was launched partly to meet the need for such a journal. The journal has grown as the Society has grown but in recent years the great increase in research into plant diseases has tended to bring to it longer articles dealing with more detailed data than formerly. Publication costs have therefore grown out of proportion to the income. We are fortunate in the able editors and competent business managers we have had to direct the progress of the journal, but it is perfectly plain that the best efforts of those in charge cannot any longer enable Phytopathology to meet the requirements of the membership and at the same time continue on the present financial basis.

In this situation, the natural and obvious course is for us to adopt the recommendations of the Council and increase the membership dues, allowing the added sum to go to the journal. This seems a very reasonable proposal and to my mind deserves unanimous support because it is apparently the simplest and most direct way, partially to meet the need.

In addition to the proposal for increase in the annual dues, there have come other suggestions which deserve thoughtful attention. There is strong belief among our members that the future security of our journal would be best assured if a permanent reserve fund could be gradually built up. The interest from this reserve fund could be used to meet the special

[1] Presented as a presidential address at the Twentieth Anniversary Meeting of the American Phytopathological Society at New York City, December 28, 1928.

needs of the journal and there would be greater financial stability. With this in mind the creation of an endowment fund for PHYTOPATHOLOGY has been proposed as a memorial to the late beloved George R. Lyman. The idea is fine. A drive for an increased number of life-memberships has also met with considerable favor. Some there are who would seek outside support, but it is a mistake, I think, for us to hope for any important contributions from outside our ranks. The men of wealth who are assisting other branches of science have had, for the most part, no contact with those problems of agriculture and forestry with which it is our responsibility to deal. Lack of contact means lack of understanding and hence lack of real interest in what we are striving for. We must count on nobody but ourselves. Let us put our shoulders to the wheel, then, and push this vehicle of science, PHYTOPATHOLOGY, over onto the smooth and solid highway of financial security.

Biological Abstracts. There is another problem from which we cannot escape. That is the problem created by the enormously rapid growth of scientific literature due to the constantly increasing volume of research. We all realize that the only practical way of meeting this situation lies in the development of a comprehensive abstracting and indexing service. *Biological Abstracts* has been launched by the Union of American Biological Societies to take care of this great need. It was a courageous and difficult undertaking. The Editor in Chief, with the assistance of his able staff and the help of a host of voluntary collaborators, has labored to develop a sound foundation for this essential enterprise. These workers have been confronted by most complex and sometimes disheartening problems, but they have stuck doggedly to the work and deserve our fullest commendation and support. To insure the permanent success of the undertaking, however, more adequate capital and a larger income are imperative. Serious consideration should be given by this as well as all other interested societies to every proposal that aims to bring these to pass.

It would help materially if, for one thing, all members of biological societies, including our own, were to subscribe individually for *Biological Abstracts.* Under the circumstances, I am inclined to look upon this as almost a professional obligation. Yet there is good reason to doubt if increased subscriptions alone will ever be able to solve the whole problem. I am compelled to believe that a large permanent endowment is necessary if *Biological Abstracts* is to operate on a basis satisfactory to the sciences which it serves. Every biological society, ours included, should lend active moral support to any appeal for endowment which is made.

In case adequate endowment cannot be obtained, why should not those departments of our universities, colleges, experiment stations, Government

offices, etc., which have to do with any branch of biology, become voluntary supporting agencies by placing in their annual budgets a definite item for *Biological Abstracts?* It would need to be but a very small percentage of the total budget. At first thought this may appear highly visionary and impracticable but it was just such voluntary support by interested educational institutions which first insured permanency to that world-famous scientific institution, the Woods Hole Marine Biological Laboratory.

If all other plans should fail, I would not look upon it as out of order to suggest that the Federal Government undertake to subsidize *Biological Abstracts* as a direct aid to the scientific work of the Nation, in which the scientific bureaus of the Government will be among the most important beneficiaries. The greatest objection to this course is that the truly international character of the undertaking would be jeopardized.

The important thing is to find some way to insure sufficient income to free *Biological Abstracts* from its present financial restrictions, to render it less dependent on voluntary assistance for the bulk of its abstracting and in this way to greatly facilitate promptness as well as completeness in publication. I suggest the appointment of a committee by this Society to further the interests of *Biological Abstracts* and to keep us in touch with the situation.

Plant Quarantine Procedure. Let us swerve sharply away from these financial questions to the kind of problem that is presented when a dangerous plant disease is first found invading new territory. We have just listened to a discussion of how the Federal Government and the States are handling such problems. This is a subject so important that it deserves the active interest of every plant pathologist. I pass on to you the query of one of our membership of long experience. "Is it not likely that future phytopathological historians, in looking back over the twenty years just ahead of us, will have reason to characterize the period as one chiefly distinguished by the discovery of and attack upon a succession of serious introduced plant diseases?" Let us give this a moment's contemplation. Now let us ask ourselves whether, even with our past experiences, we are really prepared to deal with new plant pest invasions and extensions in an intelligent and effective manner.

Would it not be an advantage if there existed a carefully considered and generally accepted course of procedure for dealing with such invasions at the very outset? Delay is costly when it comes to stamping out or holding in check such incursions; but hasty action on the basis of inaccurate or incomplete information has resulted frequently in much fruitless effort and expense. What is wanted is a wise and logical program, advancing by well coordinated steps, which could be put into effective operation in most cases just as soon as a dangerous new disease is brought to light.

One thing that strikes us immediately in regard to our present situation is the common lack of adequate provision for emergency funds and authority to deal promptly with such outbreaks. Furthermore, present procedure varies greatly. In some quarters, there seems to exist a tendency to try to cover any situation by quarantine orders before adequate surveys and studies have been conducted; while in others there is a tendency to delay all protective action until complete information is available. The evil consequences of hysteria on the one hand, and inertia on the other, can be avoided only by intelligent planning and preparation.

To aid in preventing unnatural spread of newly introduced plant pests, plant quarantines are now quite generally employed. Is there not urgent need for a statesman-like analysis and codification of the principles on which they are based? Furthermore, the general public seems to feel that there is confusing diversity of wording and complexity in the provisions of both general and local quarantine orders which might be replaced by simplification and unification along well-thought-out lines. I wish to encourage active cooperation in the improvements in these directions which are being fostered by Federal and State authorities and by the regional and national plant boards.

As we all know, there are a strong current of opposition to plant quarantines and a tendency on the part of affected commercial interests to attack individual quarantines. If every quarantine order were based on certain established and well-defined principles embraced in an accepted code, it would be much more difficult than it has been for opponents to attack individual orders. It would be necessary for them in any particular case to challenge either the assumed facts which led to the order or the particular principles on which its provisions were based. I feel that a code of jurisprudence, if you please, pertaining to plant protection must come, in time, as a guide in the development of sane, sound, and effective measures of plant defense over the whole world.

Do not such problems deserve more attention from our Society than has been given in recent years? Would it not be worth while to have at least a standing committee on plant quarantines and regulatory work to keep the members in touch with progress made each year along these lines?

Right here, I would like to express my own hearty assent to an idea set forth by our own first president, Dr. L. R. Jones, in an address before the International Congress of Plant Science at Ithaca in 1926. It was a suggestion that no plant-quarantine measure should be adopted without the appropriation at the same time of funds for investigations, the object of which would be to find a way to render such quarantine ultimately unnecessary. I believe that this plan is fundamentally sound. I think it could

and should be applied in the great majority of instances, at least, where internal quarantines are invoked.

Foreign-Pest Investigations. A year ago, this Society passed a resolution advocating extension of the study of dangerous foreign pests in their native environment. The committee appointed to represent us has reported on its initial activities. The importance of foreign investigations looms up larger than ever. To illustrate, we now realize the menace to our great western forests of Douglas fir, yellow pine, and Sitka spruce created by the advent of the European larch canker to this continent. This disease should be more thoroughly studied at once and Europe is the only logical place for this. Again, America is much concerned over the evil potentialities of the European elm disease. We are glad that the cause has been established beyond doubt, but we would feel less apprehensive over possible introduction, if practical control measures could be worked out through investigation. Such investigation can be prosecuted, of course, only beyond the Atlantic. I suggest that the Society continue this committee with an expression of our appreciation of its efforts and support of its aims.

Research on Fungicides. Let us turn now to a phase of plant pathology in which our scientific progress seems to have lagged far behind that which has been achieved in other directions. I refer to our knowledge of fungicidal materials, fungicidal action, and the relations which the state of the host, state of the pathogen and state of the environment bear to the effectiveness of fungicides on the one hand and to the presence or absence of host injury on the other.

We owe much to the handful of able investigators who are now digging patiently beneath the surface in this most important field, but the task is so great and the advance is necessarily so difficult and slow that I would like to send out a call for reinforcements.

When we squarely face the situation, we are forced to admit that in this age of chemical advancement, we, as plant pathologists, are still almost entirely dependent on the same old half-dozen or dozen chemicals or chemical combinations we were using as protective and disinfecting agents at the time this Society was founded. What is worse, even in respect to these old and familiar materials, we still know but little about their modes of action or their range of effectiveness or safety under diverse conditions. I think it would be unjust to intimate that censure is due the profession because these things are so, but I feel that we shall certainly be called to account if this state of affairs is allowed to continue any longer.

Our need for fundamental information is very real. For instance, as a guide in developing control programs for new diseases or for old diseases in new situations, we ought to have a series of monographic studies of our

chief present-day fungicides and the conditions affecting their action. Then, too, there should be some way provided whereby the new types of fungicides brought out from time to time are promptly subjected to standard tests to determine their range of applicability and their limitations. Surely we ought, also, to be probing into new chemical channels for possibilities that we can make use of in better plant-disease control. At any rate, the time seems to have arrived when sporadic, spasmodic, desultory, and purely empirical investigations on fungicides ought to be supplanted, or at least supplemented, by more adequately financed, more adequately manned, more methodical, more comprehensive, and more prolonged researches in this important field.

Because of the nature of the problems involved, research in fungicides can make the most consistent and rapid progress only where groups of adequately trained investigators, provided with suitable laboratory, greenhouse, and field equipment, can devote themselves exclusively to this type of work over long periods of years and where they can command the cooperation of skilled chemists, of plant physiologists, and of field workers acquainted with the diseases of various crops. There probably are very few of our State experiment stations that could meet these essential requirements in an entirely satisfactory manner because of limitations which cannot be overcome. The United States Department of Agriculture, however, can provide exactly the necessary conditions for such a program if furnished the necessary funds. An undertaking of this sort would be consonant with the purpose for which the Department of Agriculture was established, namely, the solution of problems affecting the agricultural prosperity of the whole Nation. I believe that the time has come when this Society should urge the Federal Government to provide greatly increased funds for use by the Department of Agriculture for fundamental research in fungicides. If this is to be accomplished, our members must help to secure strong support from all the States for the necessary Congressional appropriations.

Expansion of Cooperation. Everybody is agreed that cooperation makes possible accomplishments which could never be attained without it. There is evidence of a very rapid increase in cooperative attack on individual plant-disease problems in recent years. I believe we are warranted in encouraging still greater extension of the principles of cooperation in the field of plant pathology but success will not follow such efforts unless at the same time we do all we can to remove the stumbling blocks which always beset the highway of cooperative progress. Most of these stumbling blocks, if turned over, will be found to have on the bottom the label "selfishness" or the label "misunderstanding."

There are different sorts of cooperation, all of which are useful, but I wish to speak particularly in favor of the cooperative relations which are growing up more and more between the offices of the Bureau of Plant Industry and the plant pathology departments of the various State experiment stations. Here is a realm of cooperation in which, when successful, the Federal office, the experiment station, and the grower all benefit. Federal cooperating workers, tackling problems from a wide angle, from more than a local viewpoint, are not restricted in their movements by State boundaries. They also have fullest access to the great scientific resources of the Washington organization and are able to draw directly on the breadth of experience and the knowledge possessed by its personnel. When headquartered with one of the experiment stations, a Federal investigator usually is provided not only with required office, laboratory, greenhouse, and farm facilities but he has direct access to the advice and counsel of the local investigators and their colleagues based on their knowledge of local conditions and their practical experience with the problems in hand which cannot be secured in any other way. Furthermore, the experiment station is able to provide means of connection between the Federal workers and growers possessing the right qualifications for cooperators in field tests, etc. In addition, the interested experiment stations are in a position to see that public support is maintained in behalf of the Federal appropriations required to conduct such cooperative projects. There are many States which recognize the tremendous value to themselves of such cooperation and there is a growing realization by the Federal offices that much more can usually be accomplished per dollar expended where travel and subsistence, as well as laboratory and other costs, are reduced by having an investigator placed at an experiment station in the region where the problem to be studied exists.

Besides such Federal-State cooperation, I wish to call attention to the growing tendency toward cooperation on individual projects between different departments in the same institution. This sort of cooperation has its difficulties, of course, but the effort to surmount these difficulties is more than compensated for by the fact that it makes possible results that would otherwise be impossible. We already have examples of such collaboration between departments of plant pathology, on the one hand, and departments of genetics, plant physiology, soils, chemistry, entomology, bacteriology, agronomy, horticulture, etc., on the other. It is folly for a plant pathologist to attempt to become a specialist in every field of knowledge which must contribute to the practical solution of an economic plant-disease problem. It simply cannot be done. The only alternative lies in the type of cooperation just mentioned. I believe in the encouragement and utiliza-

tion of individual ability and individual initiative in science, as well as outside; but I believe that the greatest advances can be made only where the wisely coordinated efforts of various individual specialists are focussed effectively on one and the same problem.

Transportation and Market Pathology. My time and yours is slipping away but I would like to touch briefly on a few other topics. In its final analysis, our work as plant pathologists, has as its basic purpose the destruction of waste—waste due to diseases of plants and decay of plant products. Much progress has been made in recent years in reducing that form of waste which is due to decay in perishable products in transportation, storage, and handling. The losses from deterioration of crops after they leave the hands of the farmer, however, still continue to be far too large. It is fitting that on our program time has been set apart for special consideration of the problems of transportation and marketing pathology. We are also fortunate in the opportunity which is to be ours to observe first-hand some of the wonderful facilities which New York City provides for handling perishable products with a minimum of loss from deterioration.

Disease-free Seed and Planting Stock. I rejoice to see the rapid strides we are making at the present time in another important direction. I refer to the efforts which have been begun to put into the hands of the farmer and fruit grower seed and planting stock that will not introduce into his field the plant diseases that have hitherto everlastingly eaten into his hard-earned income. Every bit of progress in the certification of disease-free stocks attested to by trained and impartial inspectors, every forward step in the chemical and thermal treatment of seeds, bulbs, and nursery stock, and every advance in the propagation of disease-resisting varieties deserve the fullest support of our profession and of the public. We must not underestimate the difficulties involved in applying this principle generally. The path is not nearly so smooth as it looks from a distance and progress will not be so rapid as we might hope, but I believe that no tactics against plant diseases possess a sounder basis.

Graduate Fellowships. May I turn your attention for a moment to another subject. Only the development of the graduate fellowship system has made possible the rapid advance which plant pathology has achieved in the last decade. Through this system most of our younger plant pathologists, without independent means, have been able to complete their advanced training. The system, however, can be carried beyond a safe limit, and we must be watchful that this limit is not overstepped. I refer to the time when by the aid of fellowships we might prepare more well-trained investigators than there are full-time positions to send them into. We must see to it that a proper balance be maintained between the number of graduate

students and the number of full-time openings annually available. Otherwise, we may find America in the situation which is said to have existed in some branches of science in Europe before the war when eager competition was alleged to exist among young doctors of philosophy for every available $600-assistantship.

The Amateur Plant Pathologist. May I interject here something irrelevant? I want to say it and I don't know where else to put it. In the United States, at the present time, many young men of scholarly rather than commercial instincts are now inheritors of wealth. For such the sciences can provide pathways to lives full of interest and usefulness. Few branches of science can offer fuller satisfaction or a greater sense of worthwhile accomplishment than that of plant pathology. The opportunities which our larger institutions, particularly, have to interest young men of independent means to enter the field of plant pathology should not be overlooked. We need more workers who can devote their lives to pathological studies without the limitations imposed by public demands, by restricted funds, by project outlines, and by administrative duties.

In closing, may I predict that as civilization marches forward the work of the plant pathologist will grow constantly more important as well as more interesting. Science is engaged in a great campaign for the advancement of human welfare through the conquest of nature. Plant pathology holds an important position along the battle front. The world has entrusted to us the practical control of its plant-disease difficulties. Our responsibility is large and, in the discharge of this responsibility, many problems are bound to confront our profession. It is my hope that every member of this Society will take an active part in working out their solution.

OREGON STATE COLLEGE,
CORVALLIS, OREGON.

THE SECOND DECADE OF THE AMERICAN PHYTOPATHOLOGICAL SOCIETY[1]

R. J. HASKELL

Twenty years have elapsed since a small group of plant pathologists, feeling the need of an organization for the promotion of their science, conceived the idea and laid the foundations for this organization, in which we are all proud to claim membership, the American Phytopathological Society. That their belief in its cause and hopes for its success were fully justified is evidenced by this large gathering of members here to-night. We are happy to honor and to congratulate the charter members and officers on this occasion.

The history of the first decade of this Society was very ably outlined by Dr. Shear on the occasion of the 10th anniversary meeting in Baltimore. It was his suggestion at that time that the Secretary should prepare a brief historic sketch once each decade. Since this duty and privilege fall upon me, I shall very briefly mention some of our more outstanding accomplishments since 1919, and at the same time indicate a few paths along which we might with profit direct our steps in the future. I am somewhat handicapped, however, by the restriction of my time to ten minutes, thus making it necessary to review these events at the rate of one year per minute.

The growth in membership of an organization is an indication of its success. This Society started with one hundred and thirty charter members. Within ten years it had trebled its membership and to-day it is about six times its original size with 794 members.

During recent years an increase in the number of members in other countries has been very noticeable. In 1918 there were fourteen members living outside the United States and Canada. To-day there are eighty-five such members. As far as I know no special effort has been made to solicit these memberships. This indicates that our sphere of influence is extending and that foreign lands may become increasingly important sources of new members in the future.

Another indication of growth is the attendance and number of papers presented at our annual meetings. Whereas, the average attendance of members during the first decade was fifty-six, that of the second decade was one hundred and thirty-six (exclusive of 1928). The average number of papers presented per meeting during the first decade was thirty-eight, while the corresponding figure for the second ten-year period was practically

[1] Read at the Twentieth Anniversary Meeting of the Society, New York City, December 29, 1928.

double with seventy-nine. This has led to congested programs and annual discussions concerning the limitation of papers and the editing of abstracts. The method of simultaneous sessions recently followed has helped to relieve the congestion of the program. However, there still is opportunity for improvement in the general quality of the papers submitted. Could the standard possibly be raised by offering a prize or by giving honorable mention for the best contributions to the program? Is there any reason why we should be among the last of the several scientific organizations to establish prizes or medals for the stimulation and encouragement of high-class research, these awards to be given for the best publication of the year or for the best paper on the annual program?

I might point out at some length the great growth and development that have taken place in our Journal, but for lack of time I will simply say that PHYTOPATHOLOGY is now the leading publication for this science in the world. We are justly proud of it, and we wish to take this opportunity to thank again the various editors that have brought PHYTOPATHOLOGY to its present high state of development.

In looking over the past reports of annual meetings one cannot but be impressed by the work of the Advisory Board. Since its establishment exactly 10 years ago it has set its mark high up on the wall of outstanding and unusual accomplishment. One of its important functions has been the arranging and conducting of summer meetings once each year. These summer meetings have all been successful and have come to be looked upon as an established activity. I do not need to take the time even to outline the activities of the Board. These are a matter of record.

The Society is to be congratulated on the gifts and contributions that it has made to worthy causes. The members have ever been ready and willing to pass the hat when occasion demanded. To the Oberly Memorial Fund, for encouraging the compilation of bibliographies in the field of agriculture and the natural sciences, we contributed $100.49. For the Cuboni Memorial in Rome we sent $25.00 in 1922. Towards the wiping out of the deficit on PHYTOPATHOLOGY in 1920 and 1921 we made individual voluntary contributions amounting to $1,059.72. For the use of the International Congress of Plant Sciences at Ithaca we gave $200. To European phytopathologists stricken by the calamity of war we sent back-volumes and numbers of our Journal, free of charge, and since that time have given them special subscription rates.

To give to these worthy enterprises is a good practice and one that should be continued. The opportunity presents itself at this meeting to make a contribution of this sort with a two-fold purpose in mind, (1) the establishment of a memorial to a past Secretary and President of this Society

who gave unhesitatingly of his time and energy for its welfare, and (2) the establishment of a greatly needed endowment fund for PHYTOPATHOLOGY.

Two projects which have become realities during the period of this report are *Phytopathological Classics* and the Pure Culture Supply Laboratory. Mention also should be made of the important work on crown gall now going on largely because of the impetus given the subject at our Cincinnati meeting.

Any review of our history would be incomplete without mention of our Canadian and Southern Divisions which are celebrating their 10th anniversaries this year. Affiliated with the Society in 1918 they, like the earlier Western Division, have steadily progressed and thoroughly demonstrated their usefulness. We are proud of our three Divisions and extend to them our best wishes and support. The time should not be far distant when other similar branches, such as a Philippine or an Hawaiian Division, will be organized. Our name is broad enough to include any country, or group of countries, in the Western Hemisphere.

These suggestions naturally lead to thoughts of international organizations. There is need for an active, permanent, international association of plant pathologists. The International Institute of Agriculture at Rome does not seem to offer much hope. The Pacific Science Congress which meets every three years has sessions at which papers on plant pathology can be read. The International Committee of Phytopathology and Economic Entomology has been working diligently on this matter since the successful Holland Conference in 1923. It has attempted to arrange for other conferences and has made several proposals for an organization, chief among which is what might be termed an "International Association of Institutions for Plant Protection." Although this may be desirable, it does not, at the present time, seem to be entirely practical from the standpoint of our science. It would appear to be more for the benefit of persons engaged in plant quarantine and inspection than for those engaged in research, teaching, or extension work in plant pathology or entomology.

Another and probably the most important international body for us is the International Congress of Plant Sciences. The Section of Mycology and Plant Pathology is organized and officered temporarily by workers of the country acting as host. Would it not be desirable, as well as practicable, to organize this Section more permanently? An International Federation of Plant Pathologists and Mycologists made up of representatives of the Societies in the various countries could assist in coordinating one Congress with the next; plan new proposals to come before the Congress; assist the Pacific Science Congress in arranging its programs; arrange for other international meetings; encourage important researches and

surveys; facilitate the preparation and publication of compilations, monographs, indexes, etc.; and otherwise promote the science generally.

During the past decade, advances in plant pathology have been exceedingly rapid. Ten years ago, research on the virus diseases was in its infancy; copper carbonate for treating wheat to prevent bunt was unknown in this country; organic mercury compounds and several other seed and soil disinfectants had not been heard of; the Plant Disease Survey was just getting started; extension pathologists were employed in only two States; and numerous other illustrations might be cited. When one stops to consider these facts, he cannot but be impressed by the progress that has been made. Our Society has kept pace with these advances. It can be predicted with certainty that it will continue to do so, and will become an ever increasing influence for the promotion of plant pathology throughout the world.

BUREAU OF PLANT INDUSTRY,
U. S. DEPARTMENT OF AGRICULTURE,
WASHINGTON, D. C.

PHYTOPATHOLOGICAL NOTES

Black-stem disease of alfalfa, sweet clover, and red clover.[1] During a study of leguminous forage-crop failures in Kentucky, covering the past seven years, the writers have had under observation a little-known disease of alfalfa, sweet clover, and red clover which causes blackening of large areas of the stem, and suggests the name black-stem disease. The lesions on sweet clover are particularly prominent, often blackening the entire base of all the plant shoots. The lesions are usually smooth and black and, according to our observations, fruiting bodies are not produced during the current season. The disease on alfalfa is probably often confused with Sackett's bacterial disease. The true cause of black stem is not definitely known, but is being studied. It is probably of fungous origin.

Under certain conditions, the disease apparently has caused serious damage to each of the crops mentioned. Observations in 1921 and subsequently, on thick stands of second season sweet clover subjected to various clipping practices, gave the first indication of the seriousness of the disease. Plants extensively blackened on the lower portions of the stems died if cut back to the blackened area, as the buds in the blackened zone appeared to have been killed. However, if the stems were free from this disease, buds would develop into new branches following cutting of the stem above them. In 1927, the spring season was very early and wet in Kentucky and black stem was severe on sweet clover and alfalfa, killing many shoots of the latter and apparently causing death of plants in thick stands of the former. In the spring of 1928, alfalfa fields in northern Kentucky were reported to have been severely injured during the winter, many plants in fields over two years old being killed.[2] An examination of these plants showed that the crowns were dead or dying even though the roots immediately below were healthy and well filled with starch. All stages were found, from plants with crowns completely killed to plants with many of the crown buds alive. The injury to the crowns seemed to be of the same nature as the black stem trouble prevalent the previous spring. The fall of 1927 was mild and late, probably giving excellent conditions for the development of the disease until late in the fall. Perhaps fall infection of crown shoots may have accounted for their death during the winter and early spring. The injured shoots, usually about 1 to 2 inches long, were killed back completely, or the tips were killed, in which case lateral growth developed. Often, when one of these lateral branches from the base came in contact with

[1] Printed with the permission of the Director of the Ky. Agricultural Experiment Station.

[2] Many plants in wet-soil areas had heaved but these were readily distinguished from the crown-injured plants.

the dead tip, the black-stem lesions developed on the new growth at the point of contact.

In the problem of red-clover failure, the disease appears to be important as a cause of differences noted between second-season stands of adapted and unadapted lots of red clover grown at Lexington. In the spring of 1927, the stand of year-old European and American clovers[3] which started into growth varied considerably, but all, except the Italian, had a sufficient stand for a good crop. Later in the spring, marked differences in rate of growth occurred and, at blooming time, the foreign strains had but few blooms, while the best American strains bloomed profusely. A close examination at this time (June 10, 1927) showed that the first-crop shoots of French clover were practically all dead and that their present stem growth consisted of second-crop shoots. In the better American clovers with larger amounts of bloom, the degree of blooming was inversely proportional to the amount of death of the first-crop shoots. The stand of plants which remained after first cutting was directly proportional to the number of plants which retained their first-crop shoots until harvest. In other words, those lots, the hay crop of which consisted largely of second-crop shoots, died out nearly completely after first cutting, whereas those lots which bloomed most profusely and had the smallest number of second-crop shoots cut with the first crop had the highest survival after first cutting. The black-stem disease appeared to be the immediate cause of death of the first-crop shoots, although other predisposing factors, as leaf-hopper injury the previous season, may have played a part.

Whether or not black stem is concerned in winter killing of red clovers cannot be stated. It may be of significance, however, that the extent of winter killing during two winters has been in direct proportion to the injury caused to the spring growth of the same types of clovers in the spring of 1927, apparently by the black-stem disease, and this was directly proportional to death of clover plants following first cutting.

The disease develops during the spring or early summer, affecting the first cutting of alfalfa, but largely disappears during the remainder of the season and during a dry spring such as the present one (1928). On sweet clover, it probably is unimportant except in regions where the springs are long and likely to be damp. Then it causes damage only in thick stands or where grass and weeds are abundant or when the clover is clipped with the object of obtaining both a hay and seed crop. It appears to play an important part in thinning out red-clover stands the second year, especially

[3] These clovers consisted of various lots and strains of European and American origin which are being tested cooperatively with Dr. A. J. Pieters, Bureau of Plant Industry, U. S. Department of Agriculture.

in unadapted strains.—W. D. VALLEAU and E. N. FERGUS, University of Kentucky, Lexington, Ky.

A disease of Lippia caused by Sclerotium rolfsii Sacc. Sclerotium rolfsii Sacc. is known to attack a wide range of host plants. It has been found several times previously in California. However, to the writer's knowledge, its occurrence on this particular host has not been previously recorded.

Lippia canescens H. B. K. is a widely spreading, canescent, herbaceous perennial belonging to the Verbenaceae. The creeping stems become somewhat woody at the base, and form roots extensively at the nodes. The numerous upright branches arising from these stems produce a dense green turf. The plant is well adapted to light sandy soils that are moist or can be kept so by irrigation. In the interior valleys of southern California, it often is used as a lawn plant.

In August, 1927, the writer's attention was called to a disease affecting the Lippia lawn of the U. S. Department of Agriculture Cotton Field Station at Shafter, California. It had been noted for the first time during the summer of the previous year when a single, small, affected area was observed. In June, 1927, however, many new and scattered diseased areas began to appear. These increased in size rapidly during the hot summer months, causing large dead spots in the lawn.

The first symptoms appear in early June when the daily temperatures become favorable for the rapid growth of the fungus. A small, greenish yellow spot about a foot in diameter appears in distinct contrast to the green of the rest of the lawn. On close inspection, an abundance of white fungus mycelium is found on the creeping stems of affected plants and on the shaded surface of the adjacent moist soil. The tender, green parts of the plants are soon killed and when dry, form a fairly well defined, grayish white, dead spot in the lawn. The actively growing fungus mycelium at the margin of this spot attacks the healthy plants beyond and continues thus to enlarge until fall. As the protective ground cover is removed and the soil dries out, the mycelium within the diseased area forms numerous sclerotia and becomes inactive. At the center, some of the woody stems which had not been killed, resume growth (Fig. 1). As the Lippia continues to grow during the winter and spring, when the temperature conditions are unfavorable for the active growth of the parasite, the area becomes overgrown by spring, leaving no trace of the spot. Later, when conditions are again favorable, the sclerotia germinate, producing new infected areas, as was the case in 1928.

For the purpose of isolating the causal organism, a block of turf cut from the margin of a spot was brought to the laboratory, placed in a moist

FIG. 1.—Diseased areas in the Lippia lawn of the U. S. Cotton Field Station, Schafter, California. Note the plants which have resumed growth in the center of the larger areas. Picture taken October 16, 1927.

chamber, and held at room temperature. Within a few days, a vigorous mycelial growth covered the entire block. Transfers made to glucose-potato-agar slants developed as pure cultures of *Sclerotium rolfsii* Sacc. producing sclerotia abundantly. Numerous sclerotia of this fungus were also obtained from the block of infected turf.

Pure cultures grown on glucose-potato-agar plates at 30° C. for 4 days show an abundant radial growth of white mycelium. The hyphae branch freely and contiguous hyphae frequently anastomose, forming strands. Clamp connections are common in the main hyphae. Numerous, small, spherical, dark brown sclerotia soon form.

Measurements of 100 sclerotia taken from agar plates showed a variation in size of from .84 to 1.75 mm. in diameter, the average diameter being 1.09 mm. The same number of sclerotia taken from the block of infected turf varied in size from .94 to 2.01 mm. in diameter, the average diameter being 1.29 mm.

The pathogenicity of the fungus was established by successful inoculation of healthy plants grown in the greenhouse.—P. A. MILLER, University of California, Citrus Experiment Station, Riverside, California.

REPORT OF THE TWENTIETH ANNIVERSARY MEETING OF THE AMERICAN PHYTOPATHOLOGICAL SOCIETY

THE NEW YORK MEETING

The twentieth anniversary meeting of the American Phytopathological Society was held in New York City, December 28–31, 1928. The meetings were held at Teachers College, Columbia University, and the hotel headquarters were the Hotel Lincoln. About 200 members were in attendance.

There were 107 papers on the program, 9 in general session, 4 in joint session with Section G, 11 in joint session with the Mycological Section of the Botanical Society of America, 4 at a session on plant quarantines, 4 by business men on the relation of plant pathology to distribution and marketing problems, the president's address, and the remainder in sessions on cereal diseases, 18, vegetable diseases, 14, fruit diseases, 11, bacterial diseases, 12, diseases of ornamental plants, 10, and miscellaneous crops and diseases, 9.

At the first session of the Society, December 28, the subject of plant quarantines was considered. W. A. McCubbin presented a paper on "Plant Quarantines and the State"; C. L. Marlatt spoke on the "Federal Plant Quarantine and Control Work Reorganized", and C. R. Orton presented the report of the Committee on Foreign Plant Disease and Pest Investigations. Discussion was followed by a stimulating address by the President, H. P. Barss, entitled "Some Present-day Problems" (printed in this issue).

Two papers on the program of the joint session with Section G were of especial interest to pathologists—(1) "Heterothallism in the Rust Fungi" by J. H. Craigie, and (2) "Recent Studies of Curly Top" by M. B. McKay.

The production and distribution of disease-free seeds and plants were discussed at the conference on extension work. Beans, tomatoes, cabbage, and sweet potatoes were considered especially and committees were appointed to prepare summaries of the available information on supplies of disease-free seeds and plants of these four crops.

At the supper and smoker, Sunday evening, December 30, the general subject of market pathology was discussed and short talks were made by J. H. Butler representing the American Railway Express Company; A. U. Chaney for the distributors of fruits and vegetables; Frank Horne for the cold-storage interests, and H. G. Taylor for the railroads. The next morning, starting at four o'clock from the hotel, about 80 persons took the motor coach trip to the Pennsylvania Railroad terminal piers, to one of the Merchants Refrigerating Company's warehouses, and to the Washington Street fruit and vegetable wholesale houses. This trip gave those who took it a very good idea of how produce is handled in New York. It was very apparent that high-quality, well-packed and disease-free fruits and vegetables have a great advantage over inferior products on the New York market.

The twentieth anniversary dinner was held Saturday evening, December 29, at the Hotel Astor and was attended by 186 people. Charter members of the Society were identified by appropriate badges and, when asked to stand, made an impressive group. At the head table were seated ten former presidents, each of whom made brief remarks when called upon by President Barss. Dr. J. C. Arthur, the oldest charter member, speaking briefly and to the point, was heartily applauded. The Secretary-Treasurer read a short report entitled "The Second Decade of the American Phytopathological Society" (printed in full in this number of PHYTOPATHOLOGY). Following the speaking, alleged newspaper accounts of various papers from the Society's program were read. "Senator

Sorghum,'' impersonated by H. H. Whetzel, interrupted the dinner and engaged in a conversation with toastmaster Barss. He related at some length humorous experiences he had had with some of the members.

Dr. and Mrs. John Monteith and Dr. Zaumeyer then presented slides and motion pictures. A set of slides showed deceased charter members. One reel revealed charter members in action and a second depicted ''unknown species'' at their various occupations. Dr. L. M. Massey and the committee that assisted him with the dinner program received the thanks of the Society in a resolution passed at the last business meeting.

OFFICERS AND REPRESENTATIVES

The following officers were chosen:

President, R. J. Haskell, United States Bureau of Plant Industry, Washington, D. C.

Vice-President, H. S. Fawcett, Citrus Experiment Station, Riverside, California.

Secretary-Treasurer, F. C. Meier, United States Bureau of Plant Industry, Washington, D. C.

Councilor (two years), M. W. Gardner, Indiana Agricultural Experiment Station, La Fayette, Indiana.

Editor in Chief of Phytopathology (three years), H. B. Humphrey, United States Bureau of Plant Industry, Washington, D. C.

Editors (three years), J. W. Roberts, United States Bureau of Plant Industry, Washington, D. C.; A. J. Riker, University of Wisconsin, Madison, Wisconsin; H. M. Quanjer, Institut voor Phytopathologie, Wageningen, Netherlands.

Associate Editors (three years), D. L. Bailey, University of Toronto, Toronto, Canada; G. H. Godfrey, Association of Hawaiian Pineapple Canners Experiment Station, Honolulu, Hawaii; M. W. Gardner, Indiana Agricultural Experiment Station, La Fayette, Indiana; Miss Nellie Brown, United States Bureau of Plant Industry, Washington, D. C.

Business Manager (one year), F. C. Meier, United States Bureau of Plant Industry, Washington, D. C.

Advertising Manager (one year), J. F. Adams, Agricultural Experiment Station, Newark, Delaware.

Representatives on the Council of the American Association for the Advancement of Science (one year), D. Reddick, Cornell University, Ithaca, New York; C. W. Edgerton, Louisiana Agricultural Experiment Station, Baton Rouge, Louisiana.

Member of the Board of Governors of the Crop Protection Institute (three years), I. E. Melhus, Iowa State College of Agriculture, Ames, Iowa, reappointed. The other two members of the Board are: J. F. Adams and H. W. Anderson.

Member of the Permanent Committee on Necrology, A. G. Johnson, United States Bureau of Plant Industry, Washington, D. C., to replace L. R. Jones, resigned.

The following temporary committees were appointed to serve throughout the meetings:

Auditing Committee, F. M. Blodgett, H. A Rodenhiser, and A. J. Mix.

Committee on Elections, E. L. Nixon and W. D. Valleau.

Committee on Publicity, F. C. Meier, W. A. Whitney, and F. L. Drayton.

Resolutions Committee, J. H. Craigie, G. F. Gravatt, and J. C. Gilman.

REPORT OF THE SECRETARY-TREASURER, 1928

The Society started the year 1928 with 750 members. During the past twelve months we have reinstated 2 and lost 33, 20 by suspension for non-payment of dues, 9 by resignation and 4 by death. This makes a net loss of 31 and a total membership at the close of 1928 of 719. Of these, 82 are life members, paid up in full, 30 are life members, pay-

ing currently, and 607 are regular annual members. At this meeting, the secretary has 75 applications for membership and these, if elected, will bring the total membership up to 794, a net gain of 44.

The State of New York again leads this year in the securing of new members with nine applications, Wisconsin comes second with six, followed closely by Iowa and California with five each, Indiana and Minnesota with three each, Florida, Georgia, Louisiana, New Jersey, and Nebraska with two each, and eight other States with one each.

The geographical distribution of our present 720 members in good standing, at the present time, is of interest. Residing within the United States there are 590, in Canada 45, Japan 24, Australia 9, England 6, Holland 5, China, Germany, and Haiti, each 4, France 3, India, Ireland, Norway and Russia each 2, and eighteen other countries, one each.

It is significant to note that Japan has as many members as the Empire of Great Britain including all of its colonial possessions, exclusive of Canada, and that of the new foreign members to be elected at this meeting, eleven are from Japan and three from Great Britain, exclusive of Canada.

Statement of Accounts for 1928, as of December 17, 1928

Receipts:			
Balance from 1927		$1,456.28	
Annual dues: 1926	$ 4.00		
1927	28.00		
1928	1,142.79		
1929	1,699.85		
		2,874.64	
Excess dues		1.12	
Interest on checking account		37.08	
Interest on time deposit		10.00	
Time deposit returned to checking account		500.00	
Sales received with dues		1.75	
Total receipts to be accounted for			$4,880.87
Expenditures: (As per vouchers attached)			
Member subscriptions transferred to PHYTOPATHOLOGY		$1,973.00	
Secretarial work		195.25	
Postage stamps and stamped envelopes		43.74	
Stamped printed envelopes		56.52	
Printing (abstracts, preliminary announcements, ballots, nomination ballots, final program)		123.86	
Expenses of Secretary-Treasurer at Nashville meeting		85.00	
Expenses of representative on National Research Council		36.89	
Check returned by bank		5.00	
Balance as shown by bank statement attached		2,361.61	
Total expenditures and balance			$4,880.87

The available working balance of $674.74 for 1929 should be ample to care for all ordinary expenses. Should the Society wish to make appropriations, they can probably do so to the extent of about $150.00 without interfering too much with the regular work.

For the past six years, the Secretary-Treasurer has been assisted in his work for the Society by Miss Mary G. Van Meter. Over her desk most of the detail has passed and on her shoulders a large share of responsibility has rested. I have been especially fortunate,

Supplementary Statement:

Balance as above stated			$2,361.61
Amount of above receipts due PHYTOPATHOLOGY:			
For member subscriptions, 1929	$1,197.00		
For member subscriptions, 1926, 1927, 1928	45.00		
For sales received with annual dues	6.87		
		$1,248.87	
Amount due sinking fund:			
For 1925, 1927, 1928	306.00		
For 1929	132.00		
		438.00	
			1,686.87
Available working balance for 1929 expenses			$ 674.74

and I think the Society has been fortunate, in having such an efficient and interested helper who has the welfare of the Society so much at heart. I happen to know that she did not submit any bills for her work during two months of this year because she knew that the PHYTOPATHOLOGY account was becoming rather dangerously low. In closing my term as Secretary-Treasurer, I would like to express and to record my high appreciation for the excellent service she is rendering.

Since this may be the last opportunity I shall have at this meeting, I wish to say that I have enjoyed and benefited by my two terms as Secretary-Treasurer of this Society. I appreciate the honor and the opportunity for service that you have given me.

Respectfully submitted,

R. J. HASKELL, *Secretary-Treasurer.*

REPORT OF THE BUSINESS MANAGER OF PHYTOPATHOLOGY FOR 1928

Statement of Accounts for 1928, as of December 17, 1928

Receipts:

Balance from 1927			$ 585.08
Subscriptions ($498.35 for 1929, $5.00 for 1930)			2,269.30
Sales, PHYTOPATHOLOGY	$745.57		
Phytopathological Classics	2.59		
		748.16	
Advertising: 1927	237.86		
1928	870.75		
1929	27.16		
		1,135.77	
Interest on Sinking Fund and investment			322.03
Member subscriptions for 1928			1,973.00
Donation to Endowment Fund			25.00
Sinking Fund investment paid up (reinvested)			2,250.00
Surplus investment released to checking account			1,000.00
Tropical Plant Research Foundation for colored plate			496.24
Total receipts to be accounted for			$10,804.58

Expenditures:

Manufacturing PHYTOPATHOLOGY:			
Vol. XVII, No. 11	$ 276.59		
Vol. XVII, No. 12	329.38		
Vol. XVII, Index	127.93		
		$ 733.90	

Expenditures:

Vol. XVIII, No. 1	$1,131.47		
Vol. XVIII, No. 2	501.85		
Vol. XVIII, No. 3	416.83		
Vol. XVIII, No. 4	395.29		
Vol. XVIII, No. 5	620.45		
Vol. XVIII, No. 6	429.17		
Vol. XVIII, No. 7	439.21		
Vol. XVIII, No. 8	560.49		
Vol. XVIII, No. 9	1,048.81		
Vol. XVIII, No. 10	420.56		
Cuts for Vol. XVIII	739.38		
		$6,703.51	
			$7,437.41
Expenses of Editor in Chief			283.48
Postage, Editor in Chief			11.51
Secretarial work, Business Manager			94.00
Insurance on back volumes of PHYTOPATHOLOGY			47.50
Postage in mailing back volumes			11.10
Checks returned by bank			16.00
Sinking Fund reinvested			2,262.04
Duplicate subscription refunded			5.00
Balance as shown by bank statement attached			636.54
Total expenditures and balance			$10,804.58

Last year, at this time, I reported a cash balance of $585.08 plus $1,000.00 of surplus funds invested in securities. This year, as just stated, the cash balance is $636.54 and the $1,000.00 surplus has been spent. We are, therefore, not so well off this year as we were last by $948.54.

Expressing the situation in another way; the actual income for the year 1928 was $6,999.07, while the entire cost of publication for the same period was $7,918.04, or $918.97 in excess of the income. No business can continue indefinitely at that rate and so, in 1929, steps must be taken to bring the expenditures within the budget. It seems evident that we must either shorten up the harness to fit the horse, that is, reduce the size and cost of the Journal to fit the income, or we must get a larger horse. I hope that action will be taken at this meeting which will help to remedy this situation. Even if steps are taken, it is probable that the increased revenue will not begin to come in until next year and so an even closer censorship and limitation of articles submitted seems to be on the program for 1929.

Sinking Fund

The sinking fund, to which six dollars of every sustaining life-membership payment is now added regularly, totals $5,688.00. Of this $5,250.00 is now invested in first-mortgage notes as follows: 1 not of $1,000.00 at 6½%, 2 notes of $1,000.00 at 6%, 4 notes of $500.00 at 6%, and 1 note of $250.00 at 6%. The remaining $438.00, which has but recently been received, is in the Society's checking account and has not as yet been invested.

Endowment Fund

Two members have assumed that there is going to be an endowment fund and have already sent in their checks for twenty and twenty-five dollars, each.

Phytopathological Classics

In December, 1926, 1,000 copies of *Phytopathological Classics*, No. 1, were manufactured at a cost of $232.90. To date, $114.77 has been realized from the sale of slightly more than one-quarter of them, 279 copies to be exact. The remainder (721 copies) are available at forty cents, each.

Status of Subscribers

The present edition of PHYTOPATHOLOGY is 1,575, of which 1,220 copies are being mailed out. The number of subscribers in good standing on December 31, 1928, is 470 (173 domestic and 297 foreign), a gain of 50 for the year. This is a very satisfactory increase—the largest during my experience as business manager and I think probably the largest in the history of the Journal.

Respectfully submitted,

R. J. HASKELL, *Business Manager.*

REPORT OF THE EDITOR IN CHIEF OF PHYTOPATHOLOGY

Volume 18 of PHYTOPATHOLOGY contains 1,030 pages, comprising 75 articles, 26 notes, 3 reports, and 3 book reviews; 29 plates and 142 text figures. From January 1 to December 1, 1928, 114 manuscripts were submitted, of which 19 were returned for revision, and 5 rejected.

Four months has been the average length of time required for publication of papers. Manuscripts submitted during late summer and fall were delayed somewhat on account of the large amount of material on hand. They were edited promptly and were ready for publication in Volume 18, but, because of lack of funds, it was not thought wise to make the numbers larger. As will be seen from the Treasurer's report, the first nine numbers exhausted the funds available for printing PHYTOPATHOLOGY. Otherwise, more material could have been published, and some of the manuscripts would have appeared earlier.

Volume 18 is the largest volume yet published. It is not, however, necessarily any better than some of the thinner volumes. Some of the articles in Volume 18 undoubtedly are mediocre, others are moderately good, and some excellent. Some of the excellent ones were longer than necessary. Conciseness is very desirable, but the problem of attaining it cannot be solved in a short time. The editor of a democratic journal such as PHYTOPATHOLOGY can not reject summarily all manuscripts which are somewhat too prolix; neither has he time to rewrite the articles, himself. In fact, it should not be necessary. But that is what a few contributors seem to expect. Yet the subscribers are paying for prolixity: they are paying more for the Journal than would otherwise be necessary. The problem is not so simple as it might seem to those who have not had editorial experience. It is the natural desire of an editorial board to publish good papers rather than to have them published in other journals; therefore they often are accepted despite the fact that they are unnecessarily long. The idea of many contributors regarding condensation is to eliminate a few adjectives and one or two commas. As has been pointed out repeatedly, writers very often are so impressed with the mental processes by which they arrive at their conclusions that they seem quite incapable of putting themselves in the mental frame of mind of the readers. In other words, they are writing a sort of mental autobiography instead of making a clear, concise presentation of their results for the benefit of their readers. The difficulty is a fundamental one. It seems quite likely that the best method of solution is to impress upon all contributors the necessity for having some critical colleague read and comment on their manuscripts

before they are submitted for publication. This would be far better than putting the burden of revision on the editor. It is very seldom that the editor has an opportunity to discuss personally with an author the shortcomings of a paper. It is difficult to adjust many things regarding manuscripts by correspondence, whereas it is relatively easy to do so in personal conference. Furthermore, most editors sympathize with an author's desire to retain his own style. Therefore the author himself should make his own revision. Many organizations now follow the plan of having some one within the organization criticize manuscripts before they are offered for publication. The results are gratifying, indeed, to an editor, and probably also to the readers of the papers.

When the number of plates in Volumes 16, 17, and 18 is compared with the respective number of pages in these volumes, a reduction in the number of plates will be noted. A still further reduction in the number should be possible, as the paper on which PHYTOPATHOLOGY is printed is suitable for text figures. In addition to saving space, text figures have the added advantage of convenience of position. When figures are not too large to be presented on one page with the legend, they should be prepared as text figures. This applies also to combinations of small figures or drawings.

A reduction in the total number of illustrations would be highly desirable. After all, there is no particular object in publishing a picture which does not add something to the article. Most contributors have been very helpful in cooperating with the editors in the selection of the pictures to illustrate their papers; others, however, have attempted to insist that their articles be veritable picture books. It might be well to remind all contributors that it costs money to reproduce photographs and drawings. As a matter of fact, it also costs money to print words. Plates and tabular material are especially expensive. Possibly the average contributor is too little concerned with the financial problems of publication to realize that conciseness is desirable not only from the standpoint of clear presentation but that it is quite necessary also from the standpoint of economy.

There is urgent need for additional funds for publication. The Endowment Committee is submitting a report at the present meeting. If this report is adopted, and the provisions put into effect, the future of PHYTOPATHOLOGY should be reasonably well assured. With the additional funds it should be possible to publish more good papers, and the editor will not be under the necessity of insisting on too great conciseness, which sometimes is incompatible with a clear exposition of the facts presented. It seems particularly desirable that provision be made for publishing a number of good colored plates to illustrate some of the better articles and also to publish viewpoint papers and papers summarizing the present status of knowledge. In the past it has been difficult if not actually impossible to accept such papers. With adequate financial support, PHYTOPATHOLOGY should become a better and more useful journal.

E. C. STAKMAN, *Editor.*

REPORT OF THE ADVERTISING MANAGER

The advertisements for 1928 show a decrease of six pages compared to the total number for 1927. In the twelve issues of PHYTOPATHOLOGY for 1928, there was a total of 102 advertisements divided as follows: 32 one-page, 53 one-half page, 16 one-fourth page and 1 one-eighth page advertisements, or a total equivalent to 62⅝ full-page advertisements.

It is further urged upon members to consider that advertising returns are an important factor in the maintenance of PHYTOPATHOLOGY. Members can cooperate by mentioning to representatives of various companies with whom they come in contact the practical medium PHYTOPATHOLOGY offers through its advertising space. The total

purchases of supplies, equipment, etc., by our membership represents a large sum of money distributed to various commercial houses. It seems reasonable to expect in return a sympathetic as well as a financial support through advertising. However, this opinion will count for little unless each member assumes the responsibility of imparting the message. If members would interest themselves and assume a responsibility along this line, it would materially help to increase the advertising revenue and thus assist in meeting the total expense of publishing PHYTOPATHOLOGY.

J. F. ADAMS, *Advertising Manager.*

REPORT OF THE ADVISORY BOARD

The personnel of the Board for 1928 consisted of F. D. Fromme, Chairman, representative at large; J. G. Dickson, Secretary, representing the Midwest; E. L. Nixon, representing the Northeast; B. B. Higgins, representing the South; S. M. Zeller, representing the West; J. A. Stevenson, representing the United States Department of Agriculture; F. L. Drayton, representing Canada; and I. E. Melhus, representative at large.

Summer Meetings. The summer meeting of 1928 was devoted especially to the diseases of ornamental plants and was under the immediate direction of a committee composed of W. H. Martin, Chairman, W. H. Rankin, L. O. Kunkel, C. R. Orton, and L. M. Massey. The dates were August 20 to 22, inclusive, and the itinerary included visits to nurseries in New Jersey, a study of the experimental work in progress at the Boyce Thompson Institute at Yonkers, New York, and at the New York Botanical Garden, and an inspection of the work of the Bartlett Research Laboratory at Stamford, Connecticut. A number of estates in the vicinity of New York City were visited by the group. The meeting was well attended and was a most successful one from all standpoints.

National Research Council. The Board continues to function through its representative in an advisory capacity with the Division of Biology and Agriculture of the National Research Council. The accomplishments and activities of the Division for 1928 which are of particular interest to the membership of the Society are summarized briefly in the following statement. The Committee on Research Publications has been reorganized under the chairmanship of B. M. Duggar and has held several informal meetings during the summer. It is cooperating with the Committee of the National Academy of Sciences with the view of determining and satisfying the needs of scientific biological journals in the publication of original research.

In addition to the fellowships in the Biological Sciences which the Council has operated since 1923, it is proposed that fellowships in forestry and agriculture be established and a plan for instituting such fellowships has been presented to an interested Foundation for its consideration. The Committee on sulphur fellowships was discharged during the year inasmuch as its work is now completed. The contributing sulphur company has been convinced of the limitations to the utilization of sulphur for direct application to the soil because of the negative character of many of the results. The seed-germination fellowship also has been completed.

The question of the establishment of a Graduate School of Tropical Agriculture has been rather definitely determined by the Porto Rican Government and Cornell University under a plan of cooperation similar to that of the Graduate School of Tropical Medicine.

The Book on the North American rusts has gone to press.

Continued progress at the Barro Colorado Island Biological Laboratory is reported. Additional buildings, new trails and other improvements have been made and the number

of scientific workers more than equals the expectations of those who planned this station.

The Commission of Standardization of Biological Stains is preparing a book on the uses of biological stains to be published by the Chemical Foundation. The Chairman of the Commission reports that six new dyes have been certified during the past year.

The Division has established three new committees to correlate work in three very different lines of activity. They are as follows: National Finance Committee on Plant Nomenclature; Committee on the Provision and Preservation of an Adequate Supply of Experimental Animals and Plants for Investigations; and the Committee on Investigation of the Effects of Radiation upon Organisms. The activities of these committees will no doubt be of interest to plant pathologists as well as to workers in other fields of Biological Sciences.

F. D. FROMME, *Chairman.*

REPORT OF THE COMMITTEE ON ENDOWMENT FOR PHYTOPATHOLOGY

The Committee recognizes the immediate need of additional funds for publishing PHYTOPATHOLOGY, and also is of the opinion that additional money should be available for safeguarding the future. That additional money is required immediately to maintain the standard of PHYTOPATHOLOGY is quite evident. It has been necessary for the editorial board to insist on greater conciseness than sometimes is desirable in the manuscripts submitted for publication. It has been necessary, also, to be quite economical with respect to the number of illustrations. Not only that, but it has been necessary to reject some valuable viewpoint papers and summaries which would constitute valuable contributions to phytopathological literature, because it seemed that the results of research should receive first consideration. In spite of all precautions which were taken to publish only the results of research, the funds set aside for the year were exhausted in publishing nine numbers, leaving three to be paid for from next year's budget. That means that we either will have to reduce the size of the volume of PHYTOPATHOLOGY by about 25 per cent or will have to secure additional funds. It seems desirable to secure additional funds. The Committee therefore makes the following recommendations:

Immediate needs

1. That the annual dues and subscription for PHYTOPATHOLOGY be increased one dollar, the additional money to be allotted for publishing PHYTOPATHOLOGY;
2. That the drive for life memberships be continued.

Future needs

3. That an endowment fund be established, to be known as the George Richard Lyman Memorial Fund for Phytopathological Publications.

In explanation of these recommendations the Committee wishes to submit the following:

The annual dues and subscription for PHYTOPATHOLOGY should be increased in order more nearly to meet the cost of publication. The price now is ridiculously low, and it seems only fair to increase it. The additional income thus obtained should be made available immediately, to meet present needs in publication.

It seems good business to continue the drive for life memberships.

While the increased subscription and the income from life memberships will help finance the publication of PHYTOPATHOLOGY at present, the Committee is strongly of the opinion that there should be some insurance for the future. It strongly recommends, therefore, that an endowment fund be established, the interest of which will be used for PHYTOPATHOLOGY or other phytopathological publications. It seems peculiarly fitting that this fund be named the George Richard Lyman Memorial Fund, in accordance with

the suggestion made by Dr. Haskell. During his lifetime, Dr. Lyman gave so unselfishly of his time and energies to further the interests of the American Phytopathological Society and PHYTOPATHOLOGY that it seems very appropriate to establish the endowment fund as a tribute to his memory. The Committee recommends that the endowment fund be raised by voluntary subscriptions from the membership of PHYTOPATHOLOGY and by voluntary gifts from people of means who may be induced to contribute. In order to get the fund started it is recommended that the membership of the Society be circularized immediately for the purpose of inviting contributions. It is recommended, further, that hereafter the secretary-treasurer invite contributions to the fund at the time the statement of annual dues is sent out.

The Committee recommends the adoption of the report.

J. G. BROWN,
L. R. HESLER,
A. J. RIKER,
H. H. WHETZEL,
E. C. STAKMAN, *Chairman.*

COMMITTEE ON EDITING PHYTOPATHOLOGICAL ABSTRACTS

The manuscripts submitted this year show a marked improvement over those of previous years in two respects: They were for the most part within the 200-word limit, and they were sent in promptly. The final action of the Committee was to accept all abstracts which were in the mail on November 1, and, in two instances where papers were sent from outside this country, to accept an advance notice and the title of the paper in lieu of the complete draft, provided the complete paper was in hand by November 20. Only a few papers were rejected on account of tardy submittal. For most of these, there was no apparent reason for lateness other than that preparation was not begun in time, but two or three authors claimed extenuating circumstances. The Committee thought it best to make no exceptions in fairness to all who submitted their papers on time, though this was a difficult decision and was taken contrary to personal desires and despite the interest and value of certain contributions.

The Committee feels that the question of reverting to November 15 as the final date for acceptance of abstracts should perhaps be reconsidered. The regulation adopted last year was necessary for two reasons: (1) evidence of a growing tendency to submit manuscripts without much regard for the announced closing date, and (2) manuscripts frequently exceeded the prescribed length. The Committee obviously could not undertake, in condensing 400 words to 200, satisfactorily to present the author's viewpoint, and there was not enough time to refer such papers to the authors for revision.

Please bear in mind that in order to provide sufficient time for printing and distributing the abstracts in advance of the meetings, the manuscripts must be completely edited and the program arranged by about November 20. Most of the manuscripts submitted require only minor editorial attention, but there are some such that the Committee could do no greater affront to the authors than to publish them in their original form.

We propose for the ensuing year and thereafter, until further notice, that November 15 be designated as the closing date for the receipt of manuscripts for phytopathological abstracts and that this be interpreted strictly to mean that the abstracts must be in the hands of the Committee on or before that date.

Late receipts of manuscripts and length in excess of 200 words will act automatically to disqualify. In determining the number of words, the following procedure will govern: (1) The title will not be counted, nor will the article "a" in the text of the ab-

stract; (2) numerals of whatever magnitude will count as one word. In expressions of temperature, the abbreviation °C. (F.) will count as one word together with the numeral. (3) Latin binomials, including the authority, will count as one word, also common names of hosts when compound; as durum wheat, sweet potato, Japanese honeysuckle. However, authorities should not be cited in connection with scientific names unless there is real ambiguity in the use of a binomial without the authority.

Manuscripts presenting material which, in substance, has already been published will not be accepted.

The Committee also offers the following suggestions to authors to aid in the preparation of suitable abstracts.

1. Make the titles brief. Omit such introductory statements as "Studies on," "investigations of," "progress report on."
2. Write the title in lower-case letters except for the initial letter of the title and of proper names. Underscore with a solid line to indicate italics. Write the author's name in solid capitals underneath the title. In the third line, indicate the time desired for presentation and whether lantern projection is to be used. Double space the text and avoid excessive paragraphing.
3. Tables should not be used in abstracts;—they require special setting and often waste space. Their place is in finished papers. Tables may rightly be used in connection with the presentation of papers by projecting them from lantern slides.

In all enumerations of weight, measure, percentage, degrees and proportions, use numerals instead of spelling out. In other cases, spell out amounts of ten or less, and use numerals for larger amounts, but give consistent treatment to amounts in connected groups.

Write out grams, pounds, bushels, inches, per cent, but cm., mm., kg., p.p.m. (parts per million) may be employed.

The purpose of an abstract is to present clearly and succinctly the principal results and conclusions from a piece of work. The reporting of many results in detail is likely to be confusing; and since, ordinarily, an abstract is presumed to be the forerunner of a paper, it is unnecessary to present the same details in two places. On the other hand, speculation and inadequately supported generalizations have no place in an abstract. Excellent models of abstracts, both as to selection of material and manner of preparation may be found in the *Review of Applied Mycology*, and many good examples may be found also in *Biological Abstracts*.

Finally, the Committee believes that all members of this Society should assume a moral obligation to present their papers in person or withhold the abstracts.

FREEMAN WEISS (*Chairman*),
JOHN W. ROBERTS,
HARRY B. HUMPHREY,
ANNIE R. GRAVATT.

COMMITTEE ON INVESTIGATION OF FOREIGN PESTS AND PLANT DISEASES

With the development of country-wide agencies for determining the losses suffered in agriculture from insects and diseases has come a consciousness of the tremendous tax that this industry and, with it, the rest of the Nation must bear to make up for the damage done by our multitude of crop parasites. It has been conservatively estimated that our plant products are depleted to the amount of 25% annually by the inroads of insects and diseases, and it is most significant that by far the greater part of this tax on our

national economy must be attributed to pests of foreign origin. A decade or more ago the hope was cherished that, by means of a quarantine system sufficiently broad in scope and effectively administered, the host of invaders still waiting to reach our continent might be kept out with a completeness that would enable us to develop our agriculture on a permanent and stable basis. But, along with the rapid advancement in transportation methods, and large and constant increase in world-wide travel and traffic, together with the demand for foreign goods brought about by a higher general standard of living, the rising flood of materials from abroad has swelled to a point where the quarantine dam, however well constructed, seems insufficient to protect the country indefinitely from further invasion. Your committee feels that it is voicing a widespread conviction in expressing the opinion that permanent exclusion of foreign pests can scarcely be regarded as attainable and that sooner or later foreign insects and fungi are likely to be spread as far as food, climate, and natural enemies will permit.

This belief by no means implies that an open-door policy should be established. It is decidedly to our advantage to delay all unwelcome immigrants as long as possible, not only because each imported parasite lessens in a permanent way the productive capacity of the Nation, but also because each intruder disturbs the balance of agriculture, necessitating constant and costly readjustments in this industry which is perhaps the least adaptable of all to sudden change.

But, while all quarantine effort should be maintained or even strengthened, it may be expected that from time to time some of the dangerous parasites from other parts of the world will slip past the guard line and establish themselves in our midst. With the danger of such leakage constantly before us, it would seem obvious that the foresighted and profitable thing to do would be to study these prospective pests in their place of origin; an intimate knowledge of habits, life histories, means of dissemination, and methods of control might enable us not only to guard against, or at least delay, their introduction here, but if they should finally enter this country, there will be at once available a body of knowledge to enable us to cope with them immediately instead of devoting precious years to devising ways and means of control. Surely in a matter involving the basic food supply of our rapidly increasing population we may rely on the far-visioned interest of our national leadership to take these simple precautions for safeguarding its future.

Your committee notes that the necessity for investigation of this kind has already been recognized by the Federal authorities at Washington and that, on several occasions, studies of foreign parasites, already introduced or not yet introduced into the United States, have been undertaken by them. It is urged that steps be taken to formulate and put into effect a definite, permanent, and adequate program for the purpose of making such studies.

Your committee further suggests that, while colleges and private research institutions should be encouraged as far as possible in making contributions to our knowledge of foreign pests and their control, yet it would appear that leadership in this field should rest with the Federal Government since it has above all other agencies a wide experience, a deep understanding of the subject from many angles, and can most readily command both staff and financial support on a scale large enough to make the program effective. Moreover, in matters of this nature, arrangements with foreign governments are concerned and the Federal authorities are in a better position to deal with such relations than private institutions.

Your committee further recommends that this Society bring these considerations to the attention of the proper Federal authorities with an earnest request, first, that ade-

quate provisions be made for their investigation in their native habitat, in as wide a manner as possible, of insects and diseases which, because of geographical, crop, or commercial conditions, are likely to be introduced here; second, that such investigations shall include the collection of all information relating to these insects and diseases which might enable us to prevent or delay their entry here or in case of their accidental introduction at least to provide effective and immediate control; third, that in conformity with this policy, steps be taken to carry out such investigations on the following:

1. Diseases of corn, with special reference to mosaic of Hawaii which is stated by a foremost authority to be the most serious disease of this crop yet known.
2. Investigations of Fiji disease of sugar cane in the Philippines and South Sea areas.
3. Diseases of wheat, with special reference to stripe rust, known to be serious in Europe.
4. Oriental citrus diseases centered around the black-spot disease, *Phoma citricarpa*.
5. Larch canker.
6. Elm disease of Europe.
7. Soy-bean diseases in the Orient and Manchuria.
8. Certain apple diseases known to be serious in N. Japan:
   Diaporthe mali.
   Sclerotium mali.
   Valsa mali.
9. *Botrytis liliorum* in Japan.

Appendix I.

Your committee hesitates to present any detailed plan for the further organization of this program, having in mind that these matters are closely bound up with budgetary and administrative limitations and procedure, but it desires to present the following suggestions as to features in this program which ought to be given due consideration:

1. The type of investigations herein urged should be carried out primarily on a rather definite crop or project basis rather than as an attempt to collect general information over the whole range of pests in other parts of the world.
2. At the outset, attention should be centered on those localities which, because of trade volume, presence of known pests, or other considerations, may be considered as danger points.
3. Such investigations should cover host range, nature and extent of damage, life-history data, biological and artificial control, methods, means, and materials by which the parasite might be brought to this country, and such other features as might have a bearing on exclusion in the first place or control in case of accidental introduction.

Appendix II.

List of important introduced pests. (Not printed.)

Appendix III.

List of cases in which studies of diseases have been made by this country in foreign lands. (Not printed.)

C. R. ORTON, W. A. MCCUBBIN, F. D. FROMME.

REPORTS OF OTHER COMMITTEES AND REPRESENTATIVES

Phytopathological Classics. In 1927, the editors got under way plans for the preparation of two additional classics. One, the bringing together of the papers of Sir Joseph Banks on his early rust work in England by Mr. J. W. Sinden, of Cornell, and two, a translation of Tillet's early work on the smuts by Dr. H. B. Humphrey.

These manuscripts were not urged for publication at all during 1928 due to the statement by the treasurer that, in his opinion, the finances of the Society did not warrant their publication at the present time. However, both of these manuscripts can be prepared for the printer in a relatively short time when funds are available for that purpose.

H. H. WHETZEL, *Chairman.*

Representative on the Council of the A. A. A. S. Dr. Reddick reported:

1. That members of this Society are eligible to join the American Association without paying the customary entrance fee $5.00. This practice will be continued for another year but it is not yet an established policy and eventually may be abandoned.

2. That members of the American Association who are professionally engaged in scientific work are eligible for fellowship, and any such member who is not a fellow would be recommended for fellowship if the member would send him a memorandum stating merely that he is not a fellow.

3. That the Association has imposed a registration fee to help pay the extraordinary expenses of the meetings rather than to allow this expense to fall upon the "local committee," as has been the case in the past. It is unlikely that the money received in this way will pay all of the extraordinary expenses.

4. That the Association has adopted the *certificate* plan of railway ticket validation in preference to the *identification* plan as the one which is the simpler and more universally adapted to existing conditions. Some railroad companies positively require some means of identifying purchasers of special-rate tickets, others may not.

Representative on American Type Culture Collection. C. L. Shear submitted the following report:

A summary of the year's work shows a healthy growth in the activities of the collection. The collection contains more cultures and is in better shape than at any previous time. The output of cultures has increased during the year, the total being 4,761, as compared with 3,897 last year. Of the 4,761 cultures, 4,281 were bacteria, 260 fungi, and 220 yeasts. The largest part of the cultures have been furnished for teaching purposes, but a good many also for use in investigative study. Of the total, 4,178 have gone to institutions, 156 to individuals, and 427 to commercial dealers in biological supplies.

A second edition of the *Catalogue of Cultures* is ready for distribution. It includes about 650 cultures acquired since the first edition was printed and from it have been omitted about 150 cultures which had been lost or had been discontinued because impure or not true to type.

Auditing Committee. This is to certify that we have examined the books of the Secretary-Treasurer of the American Phytopathological Society for 1928 and find them to be in excellent condition. We found the subvoucher and deposit slips accounting for all the expenses and receipts, as well as canceled checks and monthly bank statements, to be all in excellent order and believe the same to be correct.

F. M. BLODGETT and H. A. RODENHISER.

Resolutions Committee. A committee consisting of J. H. Craigie, G. F. Gravatt and Joseph C. Gilman brought in the following resolutions all of which were adopted except the last, number 8.

> *Resolved:* That the Society thank the members of the General Local Committee of the American Association for the excellent arrangements provided for this meeting. Particular mention should be made of the services of Dean G. B. Pegram and Dr. S. F. Trelease in the matter of places of meeting and to Prof. M. A. Bigelow for the meeting, room arrangements.

Resolved: That the Society thank the retiring Secretary-Treasurer, Dr. R. J. Haskell, and the Editor in Chief, Dr. E. C. Stakman, for the unstinted generosity of time and energy which both men have given during their terms of office.

Resolved: That the Society express its thanks to the members of the Society in charge of the entertainment at the annual dinner, especially to Dr. L. M. Massey and to Mr. and Mrs. Monteith, and Mr. Zaumeyer for the films.

Resolved: That the Society express and record its high appreciation for the excellent services rendered by Miss Mary G. Van Meter in the office of the Secretary-Treasurer and Business Manager.

Resolved: That the Society appoint a committee to inquire into the desirability of seeking to develop an international organization for the furtherance of our science and the promotion of international cooperation and good will.

Resolved: That the members of the American Phytopathological Society recognize the great service that is being rendered by *Biological Abstracts* and would recommend that the President appoint a committee to cooperate with the Board of Editors of this Journal and to report to the Society at its annual meeting.

Resolved: That the Society authorize the appointment of a standing committee on plant, quarantine and regulatory work to keep the members in touch with progress made each year along these lines. One of the functions of this committee would be to consider the advisability of regulating the importation of pathogenic cultures.

The following proposed resolution failed to pass:

Resolved: That the Society authorize the appointment of a committee to investigate the possibilities of securing the establishment of a division of fundamental research in fungicides (and perhaps insecticides) by the Federal Government.

Permanent Committee on Necrology. The decease of five members is reported: Owen F. Burger, Frank G. O'Donnell, Flora W. Patterson, Ralph C. Thomas, and Tōji Nishida.

On account of their achievement and personal qualities, these members had won the professional respect and personal friendship of their colleagues. The American Phytopathological Society records its sense of loss in the death of these members. The formal report will be found at the end of this record.

L. R. JONES,
G. P. CLINTON,
M. B. WAITE.

ACTION OF THE COUNCIL

In addition to making the appointments mentioned in the first part of this report, the Council made the following recommendations which were approved by the Society.

1. That the incoming and outgoing officers prepare a revision of the Constitution, by-laws, and list of members to be presented at the annual meeting of the Society.

2. That Article 5 of the Constitution be amended by changing the word "beginning" in the next to the last sentence to "end." The sentence will then read, "The term of service of a Council member from a Division shall commence at the end of the annual meeting of the Society next following his election by the Division."

3. The council presents for the consideration of the Society the amendment of standing rule number 6 to read as follows: "Unless otherwise ordered, the Secretary and the

President, or, in case of his inability to attend, the Vice-President, are authorized to attend the annual meetings of the Society at the Society's expense."

4. The Council recommends the acceptance of the resignation of E. C. Stakman, M. N. Levine, and L. R. Hesler as Editors of PHYTOPATHOLOGY.

5. Dr. H. B. Humphrey is extended the opportunity of the editorship of PHYTOPATHOLOGY if he wishes that in preference to the secretary-treasurership to which he has been duly elected. If he accepts the editorship and resigns the secretaryship, it is recommended that F. C. Meier, who received the next highest number of votes for secretary-treasurer be declared elected.

6. It is recommended that thanks be extended to the Advertising Manager for his past services, and that hereafter 10% of the advertising receipts be given the Advertising Manager. It is believed that this will result in increasing the net revenue to PHYTOPATHOLOGY from advertising.

7. The report of the Endowment Fund Committee is approved and the adoption of the methods proposed for increasing the income of PHYTOPATHOLOGY is recommended to the Society.

8. It is recommended that the Committee on revision of the Constitution investigate the question of the appointment of trustees to care for the sinking fund and the endowment fund of the Society.

9. It is recommended that subscription rates for PHYTOPATHOLOGY be increased one dollar per year and that the reduced rates to European subscribers be discontinued.

10. The incoming President is authorized to appoint as delegates any members who may be attending the Fourth Pacific Science Congress in Java, May, 1929.

OTHER BUSINESS

The reports of officers, committees, and representatives, as printed above, were accepted. The report of the Committee on Foreign Plant Diseases and Pests and that of the Committee on Editing Abstracts were ordered printed in the proceedings of the meeting.

Dr. Donald Reddick reported that those desiring information concerning transportation and general plans for the 1930 International Botanical Congress in Cambridge, England, can get in touch with Dr. G. H. Coons, Bureau of Plant Industry, Washington, D. C., who is on a general committee of American botanists that has these matters in charge. It was further stated that the arrangements for the sessions on phytopathology at the Congress were adequate and that the fears that they would not be were caused by a typographical error in the early announcement.

It was moved and carried at the second business meeting that the Advisory Board of the Society be abolished and that its functions be taken over by the Council.

Dr. I. E. Melhus extended an invitation to the Society to visit Ames and, if desired, to hold some of our sessions there. Professor Whetzel moved that the invitation be accepted with thanks, and that the matter of holding sessions at Ames be considered by those in charge of the meeting.

The Committees on Endowment Fund and on Foreign Plant Diseases and Pests were ordered continued.

Dr. L. R. Jones moved that the thanks of the Society be expressed to Miss Van Meter and that the Secretary determine the amount of the Society's financial indebtedness to her.

Dr. A. G. Johnson moved a vote of thanks to the retiring Secretary-Treasurer for his services.

R. J. HASKELL, *Secretary.*

IN MEMORIAM

TŌJI NISHIDA

APRIL 15, 1874—JUNE 19, 1927

Tōji Nishida received the degree of Bachelor of Agriculture from the Sapporo Agricultural College (now Hokkaido Imperial University) in 1899 and the degree of Doctor of Agriculture from the same institution in 1919, specializing throughout in mycology and plant pathology.

From 1899 to 1904, he was on the staff of the Imperial Agricultural Experiment Station at Nishigahara. From 1904 to 1914, and again from 1923 to 1924, he served at the Kyushu branch of the Imperial Experiment Station at Kumamoto, except during the period of the Russo-Japanese war when he served in the Japanese Army. From 1914 to 1923, he was plant pathologist and director of the Kobe Substation of the Imperial Quarantine Service. From 1924 to the time of his death, he attended the Kumamoto Medical College with a view of specializing on comparative plant and animal pathology.

FRANK GETCHELL O'DONNELL

OCTOBER 20, 1896—JANUARY 11, 1928

Frank Getchell O'Donnell received the degree of Bachelor of Engineering from Schuylkill Seminary in 1917 and the degree of Bachelor of Science from Pennsylvania State College in February, 1920, specializing in plant pathology in the latter institution.

Previous to and immediately following his graduation from Pennsylvania State College, he was employed by the Pennsylvania Agricultural Experiment Station as Field Assistant in potato-disease investigations. From April 20, 1920, to the time of his death, he was on the staff of the Federal Horticultural Board, U. S. Department of Agriculture, advancing from field assistant to assistant pathologist. With the Federal Horticultural Board his earlier work was on the control of potato wart and his later work was on seed disinfection.

To all who knew him, his life was one of promise because of his broad foundation in science, his ingenuity in adapting or devising methods and apparatus to suit his needs, his uncanny knack of handling pure cultures, his unlimited patience, and his painstaking accuracy in conducting experiments.

OWEN FRANCIS BURGER

JUNE 8, 1885—JANUARY 26, 1928

Owen Francis Burger received the degree of A.B. from Indiana University in 1909, the degree of M.S. from the University of Florida in 1911, another M.S. from Harvard University in 1915, and the degree of Sc.D. from Harvard University in 1916.

From 1909 to 1911 he assisted in plant pathology, Florida Agricultural Experiment Station; from 1911 to 1913 he served in the same institution as assistant plant pathologist; from 1913 to 1916 he held scholarships at Harvard University; from 1916 to 1918 he was instructor in plant pathology, Citrus Experiment Station, University of California; from 1918 to 1920 he was pathologist in the Office of Fruit Diseases, Bureau of Plant Industry, U. S. Department of Agriculture, and from 1920 to the time of his untimely death he was head of the Department of Plant Pathology of the Florida Agricultural Experiment Station.

He was the author of many papers dealing chiefly with fruit diseases. He was an able investigator, capable administrator, and excellent cooperator, combining in all a most congenial, jovial, and friendly personality. Truly it can be said that here was one who served with courtesy and consideration for all.

MRS. FLORA WAMBAUGH PATTERSON

SEPTEMBER 15, 1847—FEBRUARY 5, 1928

Flora W. Patterson prepared for her life work as a mycologist at Radcliffe College and the Gray Herbarium. Practically all of her work in her chosen profession was carried on in the U. S. Department of Agriculture during the years from 1895 to 1923, the latter year marking her retirement from active duty. She was, therefore, one of the original and long-time members of the Bureau of Plant Industry.

Mrs. Patterson's work dealt chiefly with the determination and care of the specimens that found their way into her department's herbarium. Such work, while very valuable to others, is time consuming and often prevents the one engaged in it from pursuing outside scientific investigations. Such publications, consequently, that Mrs. Patterson issued consisted of lists of fungi and short articles on fungi of economic or special interest. Her work was largely in the nature of service to others rather than search for individual renown.

Service seems to have been the keynote of her life, as we read the account of it as published by a co-worker. The effective but quiet aid given her family, as well as scientific friends, in the end, counted more than a brilliant personal career. For after all, when the end comes, we measure people by service rendered rather than by their ambitions.

RALPH CLEON THOMAS

APRIL 9, 1892—DECEMBER 25, 1928

Ralph Cleon Thomas received the degree of Bachelor of Science from the Virginia Polytechnic Institute in 1917 and the degree of Master of Science from the same institution in 1919, specializing in agronomy, plant pathology, and botany. From February, 1923, to August, 1923, he took special work in bacteriology at the Michigan Agricultural College. During the summer of 1924, he took special work in plant pathology at Cornell University.

During the first part of the school year, 1917–18, he was student assistant in bacteriology and plant pathology at the Virginia Polytechnic Institute. From March, 1918, to April, 1919, inclusive, he served in the Medical Corps, U. S. Army, having overseas service from July, 1918, to April, 1919. From August, 1919, to November, 1919, he was assistant county agent in Virginia. From November, 1919, to September, 1922, he was extension plant pathologist at the Virginia Polytechnic Institute. From February, 1923, to August, 1923, he was graduate assistant in bacteriology at Michigan Agricultural College. During the school year 1923–24 he was a teacher in Jackson Junior High School, Roanoke, Virginia. From October, 1924, to the time of death, December 25, 1928, he served as agent in the Office of Tobacco Investigations, Bureau of Plant Industry, United States Department of Agriculture, working on the diseases of tobacco in the Southern states.

The genuineness of his friendship was indicative of his noble character. Among God's noblemen, none ever was more merciful to his opponents; none more charitable to the needy; and none more thoughtful of the unfortunate and neglected. He was a veritable incarnation of Christianity, and though taken in the flower of young manhood, Ralph C. Thomas will always be alive in the memory of his friends.

MINUTES OF THE FIELD MEETING OF THE SOUTHERN SECTION OF THE AMERICAN PHYTOPATHOLOGICAL SOCIETY, JULY 11–13, 1928

The Southern Section of the American Phytopathological Society assembled at Experiment, Georgia, July 11, 1928, for the summer field meeting. Thirty pathologists from seven States and the District of Columbia took part in the tour, eighteen making the entire trip. After a brief discussion of the plan and purpose of the meeting, the remainder of the morning was spent in viewing and discussing pathological work in progress at the Georgia Experiment Station. At noon, the visitors were guests of Chairman B. B. Higgins at a luncheon served on the station grounds. The afternoon was spent in visiting peach orchards, bean and pepper fields, a cannery near Griffin, Georgia, and some peach-fertilizer plats where the effect of fertilizers on winter injury and on peach bacteriosis was observed. At 6:30 P. M., the visitors were tendered a barbecue by the experiment station.

On the morning of the 12th, the group drove to Fort Valley where Dr. Lee Hutchins demonstrated his work on "Phony" peach and Mr. J. Dunegan discussed peach bacteriosis. After luncheon, the party drove to Sylvester to see a large cantaloupe farm and packing house, and then on to Tifton for the night.

At the business meeting held that evening, it was agreed that another field meeting should be scheduled for 1929 in a territory to be decided upon during the winter. The following officers for 1929 were elected at this meeting for the Southern Section of the American Phytopathological Society:

R. F. Poole, North Carolina, Chairman.

H. H. Wedgworth, Mississippi, Secretary.

B. B. Higgins, Georgia, Representative on Council, Am. Phy. Soc.

Early in the day of July 13, a visit was made to the Coastal Plain Experiment Station where research on cantaloupe and tobacco disease was in progress. Other diseases of special interest were found here. At Thomasville, the visitors were entertained at a delightful luncheon by the local Chamber of Commerce, following which a trip was made to some of the local pecan groves to observe the work on pecan diseases conducted by J. B. Demaree, pathologist in charge of the Pecan Disease Laboratory of the U. S. Department of Agriculture. Led by O. C. Boyd, pathologist, State Board of Entomology, stops were made also at near-by melon fields.

The meeting ended officially here, but a number of the visitors continued to the Tobacco Experiment Station at Quincy, Florida.

The Section tendered a vote of thanks to L. M. Hutchins, John Dunegan, Frank Van Haltern, R. C. Thomas, J. B. Demaree, and O. C. Boyd for the hearty spirit of cooperation shown in planning and conducting the meeting and in arranging to entertain the visitors in their respective localities.

B. B. HIGGINS, *Chairman.*
V. H. YOUNG, *Secretary.*